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Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program

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RELIABILITY AND QUALITY ASSURANCE PUBLICATION

NASA
National Aeronautics and Space Administration

NAS 1.22/3:

PREFACE

Date: Oct. 1979

This publication establishes common safety, reliability, maintainability and quality provisions for the Space Shuttle Program.

NASA Centers shall use this publication both as the basis for negotiating safety, reliability, maintainability and quality requirements with Shuttle Program contractors and as the guideline for conduct of program safety, reliability, maintainability and quality activities at the Centers. Centers shall assure that applicable provisions of the publication are imposed in lower tier contracts. Centers shall give due regard to other Space Shuttle Program planning in order to provide an integrated total Space Shuttle Program activity.

In the implementation of safety, reliability, maintainability and quality activities, consideration shall be given to hardware complexity, supplier experience, state of hardware development, unit cost, and hardware use. The approach and methods for contractor implementation shall be described in the contractor's safety, reliability, maintainability and quality plans.

This publication incorporates provisions of NASA documents: NHB 1700.1 "NASA Safety Manual, Vol. 1;" NHB 5300.4(1A), "Reliability Program Provisions for Aeronautical and Space System Contractors;" and NHB 5300.4(1B), "Quality Program Provisions for Aeronautical and Space System Contractors." It has been tailored from the above documents based on experience in other programs. It is intended that this publication be reviewed and revised, as appropriate, to reflect new experience and to assure continuing viability.

Questions concerning application of this publication to specific procurements should be referred to the procuring NASA Installation. General questions concerning the intent of the provisions herein should be referred to the NASA Headquarters, Director, Space Shuttle Program, Washington, D.C. 20546.

This revision is an administrative updating of 5300.4 (1D-1) to incorporate the following changes approved by the Program Director: S00705R1, SO1038AR1, SO1475, and SO2233.

This Handbook will be revised by page changes.

NHB 5300.4 (1D-1) dated August 1974 is canceled.

M. S. Malkin
Director,
Space Shuttle Program

Distribution:
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Revised paragraphs are identified by lines in the margins of the publication.

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TABLE OF CONTENTS

Par. *Page*

CHAPTER 1: INTRODUCTION

1D100 Approach 1-1
1D101 Relation to Other Contract and Program Requirements 1-1
1D102 Motivation 1-1
1D103 Independent Evaluations for NASA 1-2
1D104 Information Requirements List (IRL) and Information Requirements Descriptions (IRD's) . 1-2

CHAPTER 2: SAFETY

1D200 Safety Management 2-1
1D201 System Safety 2-3
1D202 Industrial Safety 2-6
1D203 Test Operations Safety 2-7

CHAPTER 3: RELIABILITY

1D300 Reliability Management 3-1
1D301 Reliability Engineering 3-2
1D302 Testing 3-7

CHAPTER 4: MAINTAINABILITY ASSURANCE

1D400 Management 4-1
1D401 Program Elements 4-1

CHAPTER 5: QUALITY ASSURANCE

1D500 Management and Planning 5-1
1D501 Design and Development Controls 5-3
1D502 Identification and Data Retrieval 5-5
1D503 Procurement 5-6
1D504 Fabrication Controls 5-12
1D505 Testing, Inspections, and Evaluations 5-14
1D506 Nonconforming Articles and Materials 5-19
1D507 Metrology 5-22
1D508 Stamp Controls 5-24
1D509 Handling, Storage, Preservation, Marking, Labeling, Packaging, Packing and Shipping 5-24
1D510 Sampling Plans, Statistical Planning and Analysis 5-26
1D511 Government Property Control 5-26
1D512 Flight Test/Ground Operations 5-28

Appendix A—Glossary of Terms a-1

CHAPTER 1: INTRODUCTION

1D100 APPROACH

The safety, reliability, maintainability, and quality assurance activities require:

1. Thorough planning and effective management.
2. Definition of the major safety, reliability, maintainability and quality assurance tasks and their place as an integral part of the design and development process.
3. Evaluation of hardware safety, reliability, maintainability and quality through analysis, test, review, and assessment.
4. Timely status indications by formal documentation and other reporting to facilitate implementation of the safety, reliability, maintainability and quality assurance efforts.
5. Compatible requirements among manufacturing, test and operational sites.

1D101 RELATION TO OTHER CONTRACT AND PROGRAM REQUIREMENTS

The safety, reliability, maintainability and quality assurance activities set forth in this document shall complement and support other required functions, but duplication of contractor efforts shall not be incurred as a result of overlapping or interfacing requirements contained elsewhere in the statement of work or in other parts of the contract. Interfacing program activities and requirements shall be referenced as part of the contractor's Safety, Reliability, Maintainability and Quality Plans. Provisions for fulfilling all requirements of this document shall be included in these plans or in other plans and referenced in the Safety, Reliability, Maintainability and Quality Plans.

1D102 Motivation

The contractor shall maintain a product oriented motivation (awareness) program planned and implemented as an integral part of, and making maximum use of, the existing motivational effort. The program objective shall be the prevention of human error by instilling in individuals performing on the contract and on critical subcontracts thereunder, an awareness of their personal responsibility for Space Shuttle mission success and motivating the exemplary performance necessary to achieve this success. The program shall include the following as a minimum:

1. Goal setting and measurement to provide documented practical goals and performance standards for the reduction and elimination of human errors at organizational and individual employee levels.
2. Error Cause Identification and Removal System for detecting human errors, relating them to an identifiable cause and action to remove the cause.
3. Methods to obtain and distribute Space Shuttle motivation information and materials to concerned contractor personnel, those of subcontractors and vendors supplying critical flight and ground support hardware and software.
4. Motivational (awareness) indoctrination for contractor Space Shuttle supervisory personnel and indoctrination of the work force in workmanship needs.
5. Recognition means for personnel who demonstrate their awareness through exceptional craftsmanship, error free workmanship and attention to careful performance in their job responsibility.
6. Existing motivation (awareness) program of suppliers of critical flight and ground support hardware/software shall be reviewed for compliance with the intent of these requirements in motivating supplier personnel and their sub-suppliers to exemplary performance. Provisions for

fulfilling all or part of the requirements on critical subcontracts will be authorized by specific contract direction.

1D103 INDEPENDENT EVALUATIONS FOR NASA

NASA reserves the right to use representatives of NASA-selected contractor(s) in its evaluations of safety, reliability, maintainability and quality assurance activities. These contractors may:

1. **Provide technical support to NASA.**
2. **Determine effectiveness of and recommend improvements to system and subsystem contractor's and supplier's safety, reliability, maintainability and quality assurance efforts.**

1D104 INFORMATION REQUIREMENTS LIST (IRL) AND INFORMATION REQUIREMENTS DESCRIPTIONS (IRD's)

Information Requirements List and Information Requirements Descriptions shall be included in the contract.

CHAPTER 2: SAFETY

1D200 SAFETY MANAGEMENT

The contractor shall maintain a safety activity planned and developed in conjunction with other functions to assure that hazards are identified and resolved. In addition to the development of a Safety Plan, safety requirements and tasks will be reflected as appropriate in other Program Plans. Applicable safety requirements and tasks shall be included in the basic management systems, design verification documents, overall system analyses, and system engineering requirements definition, and design review practices. Major elements of safety management are:

1. *Safety Plan.* The contractor shall prepare a Safety Plan which complies with the requirements identified in this document. The contractor shall place special emphasis on describing how he/she will assure the identification, elimination and/or control of potential hazards which lead to injury, loss of personnel and/or damage or loss of flight or ground hardware throughout the complete cycle of the program. This Safety Plan will integrate and describe the relationship of all safety activities. Existing documents may be referenced and submitted as part of the Safety Plan. The Industrial Safety/Occupational Health and Safety Plan shall be incorporated or attached to the Safety Plan. The Safety Plan should provide in a matrix form, or some equivalent format, the clear/concise title of all the specific tasks to be covered by the plan, with the following additional information about each task.

   a. Other program plans which are involved.

   b. Contractor organization(s) involved in the execution of each task.

   c. The contractor program procedure/instruction which describes how each task is performed.

   d. The start and completion schedule of each task including program schedule or milestone which the task supports.

   e. The output products of each task including identification of deliverable data.

   f. The resources or staffhours required to execute each task.

2. *Site Safety Plans.* Separate Site Safety Plans shall be prepared prior to construction, activation and/or operations phases of site activities as applicable.

   a. If NASA has a site construction contract with a contractor other than a prime Shuttle contractor, and if the prime Shuttle contractor(s) will be onsite during the construction phase, both/all contractors under NASA sponsorship shall outline their safety approaches, responsibilities, and interfaces to assure development of compatible contractor Site Construction Safety Plans.

   b. If NASA's prime Shuttle contractor or subcontractor has the site construction contract, the responsible contractor shall provide the Site Construction Safety Plan.

   c. These guidelines also apply to remodeling or renovating existing sites and, in a similar manner, to activation and operations phases where contractors are engaged in joint activities.

3. *General Considerations.* Safety requirements for planning, design, manufacturing, testing, and operations shall be developed and documented as an integral part of the contractor's activities. The contractor shall establish check points and feedbacks which provide management visibility to assure that all safety considerations have been evaluated and completed prior to commencement of major activities or milestones. The contractor shall establish a system to assure that there is compatibility of design, test, and operational documentation with the as-built hardware. The safety

considerations shall be revised and updated as design and operational changes dictate. The following areas are representative examples where major safety consideration and analysis are required.

a. Trade studies including risk comparison in areas such as abort, equipment redundancy, crew egress, operational consideration, etc.

b. Detailed design analyses, including results of failure mode effects analyses.

c. Horizontal and vertical flight test programs.

d. Vehicle, GSE and subsystem manufacturing, fabrication, assembly, checkout, maintenance, and handling.

e. Safety aspects of integrated facility, GSE, and vehicle hardware operations.

f. Compatibility between a person and machine.

g. Compatibility between vehicle and ground support equipment.

h. Compatibility between vehicle systems and interfacing vehicles and/or cargo.

i. Crew and vehicle operations and procedures.

j. Interlocks to obviate personnel injury or loss of hardware.

k. Warning and protective devices.

l. Compatibility of safety factors with test and operational stresses.

m. Verification that changes and modifications have been incorporated and are compatible prior to critical systems operations.

n. Break-up and survival of orbital debris.

Emphasis should be given to these safety considerations in relation to: mission profile, event, and environment; abort; escape; critical time periods for each subsystem necessary for crew survival; systems/subsystem interfaces; caution and warning systems to provide timely information to ground and flight personnel; testing; training; servicing; handling; fail operational/fail safe combinations; automatic and manual functional redundancies; switching to backup modes; failure detection and display; and public safety.

4. *Organization.* The contractor shall establish a centralized safety organizational element clearly identifiable within the management structure to assure that all safety activitites shall have timely planning, implementation, and effective technical safety management.

5. *Safety Coordination.* The System Safety, Industrial Safety, and Test Operations Safety activities shall be fully coordinated with each other and with launch site safety activities to ensure an effective and integrated total safety effort and to avoid redundant effort among technical disciplines.

6. *Safety Audits.* NASA audit teams will periodically audit the contractor's safety activities. The contractor shall support these audits as required. The contractor shall provide data upon request which will verify internal conformance and the conformance of subcontractors to safety requirements. The contractor shall establish a schedule of audits of subcontractor safety efforts at least one year in advance and shall maintain a file of audit reports available to NASA upon request.

7. *Safety Training and Certification.* The contractor shall provide training and certification for personnel who are to be involved in hazardous operations and activities. The contractor shall identify positions requiring training and certification. A current status of certification shall be maintained oriented to missions, configurations, and locations. Protective devices and emergency equipment shall be identified and included in safety training. Hazards will be brought to the attention of trainees. Proficiency demonstrations of training, to the degree feasible, are required for hazardous operations.

8. *Mishap Investigations and Reporting.* The contractor shall investigate and report accidents/incidents (including injuries to personnel and damage to property) occurring during manufacturing, testing and operations. The contractor shall be prepared to provide technical assistance to NASA boards investigating mishaps which occur within its jurisdiction.

9. *Risk Management.* The contractor shall prepare and maintain risk management data in a composite form for management overview and decision making purposes. This data shall be assimilated from each discipline and shall include risks and hazards identified by efforts such as hazard analyses, failure mode and effect analyses and human factors analyses.

10. *Program Reviews.* The contractor shall provide the means for reviewing safety status as part of each program review. Risk management data shall be made available and/or presented at program progress reviews and milestone reviews.

11. *Operational Readiness Inspections (ORI).* The contractor shall perform an operational readiness inspection prior to performing any operation or test which (a) is potentially hazardous to personnel or hardware, (b) has high risk in terms of program importance, or (c) involves test hardware, facilities or effort having high dollar value. The ORI shall include a safety assessment of facilities, equipment, test articles, operational procedures and personnel capability.

12. *Subcontractors.* The contractor shall select and invoke safety requirements specified in this document, as appropriate, on the subcontractors who provide subsystems which, in either normal or emergency operational modes, may present hazards impacting system or personnel safety.

1D201 SYSTEM SAFETY

1. *System Safety Analysis.* The contractor shall establish and identify procedures and instuctions which will be used to execute all safety analyses. The contractor shall perform system safety analyses assuring that:

   a. Safety is designed into the product; known hazardous conditions which cannot be eliminated through equipment design or operational procedures are controlled or reduced to an acceptable level. Residual hazards shall be tracked and identified to NASA.

   b. Hazard level classifications are used to provide a continuous tracking and status of severity with the aim of reducing catastrophic and critical hazards to controlled levels within the constraints of risk management.

   c. Results of previous trade studies and analyses are considered.

   d. Other related analyses, such as failure mode and effect analyses, are considered to preclude duplication of analytical work.

2. *System Safety Guidelines and Constraints.* The contractor shall develop and establish System Safety guidelines, constraints, and requirements to guide the vehicle systems design, GSE design, and operations planning. These criteria shall satisfy programmatic guidelines and constraints, system safety goals, and other top level safety objectives, and may be extracted from existing safety guides such as the MSC 00134 Space Flight Hazards Catalog and guidelines from previous studies. The guidelines and constraints developed shall be specified in the applicable vehicle and GSE requirements.

3. *Safety and Trade Studies.* The contractor shall perform safety studies and shall develop safety inputs to support trade studies. Specific inherently hazardous characteristics of the alternatives being considered shall be identified. The contractor shall document rationale to support the selected concept and to demonstrate that it includes the optimum safety provisions consistent with program objectives, risk management, performance, cost, and schedules.

4. *Hazard Analysis*

   a. The contractor shall perform a qualitative hazard analysis to identify hazards and assure their resolution. Hazards shall be identified and classified in accordance with the hazard levels defined in the glossary of terms. The contractor shall provide for the periodic performance and

refinement of hazard analysis and periodic assessment of achieved versus specified requirements. *All hazards* including those resulting from failures, irrespective of subsystem or component redundancy, *shall be analyzed.* In addition to hazards resulting from failures, those emanating from normal or emergency equipment operations, environment, personnel error, design characteristics, and credible accidents shall also be analyzed. The contractor shall also identify and eliminate or control any failures or malfunctions that could independently or collectively present a hazard to interfacing hardware and assure that normal operation of a hardware item cannot degrade the safety of interfacing hardware or the total system.

b. Early hazard analysis emphasizing design shall be the baseline of an expanded analysis. The hazard analysis shall be updated as the program progresses, providing continuity and covering the interrelated areas of design, operations, and vehicle subsystem integration.

c. In addition to the design and operational hazards identified, the following inputs shall be included in the hazard analysis:

(1) Credible accidents, including their definition and magnitude.

(2) Residual hazards (catastrophic and critical) which were not eliminated by design in previous studies.

(3) Hazards whose corrective action(s) proposed during previous studies have not been accomplished and/or verified by test or analysis.

5. *Hazard Analysis Elements.* In performance of the hazard analysis, consideration shall be given to at least the following elements:

a. Isolation of energy sources/propagation paths.

b. Cryogenics and Propellants: their characteristics, hazard levels, and quantity/distance constraints, handling, storage, and transportation safety features, compatibility factors, etc.

c. Proposed system environmental constraints.

d. Use of explosive devices and their hazard constraints.

e. Extra/intravehicular activities.

f. Effect of transient current, electromagnetic radiation, and ionizing radition.

g. Design of controls to prevent inadvertent activation of initiation circuits.

h. Crash worthiness and ditching.

i. Documentation for safe operation and maintenance of the system.

j. Training and certification pertaining to safe operation and maintenance of the system.

k. Egress, escape, rescue, survival, and salvage.

l. Life support requirements and their safety implications in manned systems.

m. Fire and explosion sources, detection, warning, and protection.

n. Resistance to shock damage.

o. Toxicity sources: detection and warning.

p. Man-machine relationship.

q. System interactions.

r. Meteoroid penetration.

s. Docking consideration/cargo handling.

t. Long-term storage.

6. *Hazard Reduction Precedence Sequence.* To eliminate or control hazards, the contractor shall use as a minimum the following sequence or combination of items:

   a. Design for Minimum Hazard. The major goal throughout the design phase shall be to ensure inherent safety through the selection of appropriate design features as fail operational/fail safe combinations and appropriate safety factors. Hazards shall be eliminated by design where possible. Damage control, containment and isolation of potential hazards shall be included in design considerations.

   b. Safety Devices. Known hazards which cannot be eliminated through design selection shall be reduced to an acceptable level through the use of appropriate safety devices as part of the system, subsystem, or equipment.

   c. Warning Devices. Where it is not possible to preclude the existence or occurrence of a known hazard, devices shall be employed for the timely detection of the condition and the generation of an adequate warning signal. Warning signals and their application shall be designed to minimize the probability of wrong signals or of improper personnel reaction to the signal.

   d. Special Procedures. Where it is not possible to reduce the magnitude of existing or potential hazard through design, or the use of safety and warning devices, special procedures shall be developed to counter hazardous conditions for enhancement of ground and flight crew safety. Precautionary notations shall be standardized.

7. *Hazard Closure Criteria.* A hazard shall be considered closed only if:

   a. The hazard has been eliminated by design and design accomplishment has been confirmed; or

   b. The hazard has been reduced to an acceptable level (controlled hazard) in accordance with the Hazard Reduction Precedence Sequence, and this reduction has been verified by way of a successful completion of the required test programs, analytical studies, and/or training programs; or

   c. The hazard has been assessed and the risk has been accepted by NASA.

8. *Residual Hazards.* Residual hazards (catastrophic and critical) shall be specifically identified to NASA. The contractor shall establish a tracking system to provide the status of identified hazards and to flag catastrophic and critical hazards. Continuation of effort to eliminate or reduce such hazards shall be accomplished throughout the program by maintaining awareness of new safety technology or devices being developed and their application to the residual hazards. Rationale for acceptance of residual hazards shall be documented.

9. *Human Engineering.* Procedures shall be developed to assure the application of safety related human engineering principles during design, development, manufacture, test, maintenance, and operation of the system or subsystem to minimize human error.

10. *Interface with Other Program Functions.* Safety shall be coordinated and integrated with the other program functions to avoid overlaps and conflicts among the technical disciplines, and to establish an integrated effort. This coordination shall include: the delineation of responsibilities, management structure, joint analyses, reporting procedures, feedback of test data and corrective actions, use of failure mode and effects analysis, single failure point summaries, or other analytical techniques to identify hazards.

11. *Waivers and Deviations.* For proposed waivers and deviations, the contractor shall establish a means to analyze the safety impact.

12. *Hazard Data Collection, Analysis, and Corrective Action.* Using existing data systems wherever practical, a system for hazard reporting, data storage, and feedback of corrective action shall be formulated. This will involve a closed-loop system for collecting analyzing, and recording all reported hazards that occur during the period covered by the contract.

13. *Safety Data.* Safety data provided by NASA shall be used as an aid to prevent and eliminate design and operational deficiencies.

14. *Specifications and Procedures Review.* Contractor generated specifications and procedures for manufacturing, testing, and operations shall be reviewed to assure that these activities do not negate the inherent safety of the design.

15. *Safety of Government Furnished Equipment.* When the overall system includes components of subsystems furnished by NASA, the contractor shall analyze the safety impact on the Shuttle system of the GFE; safety data on the GFE shall be provided by NASA. Where examination of these data or testing by the contractor indicates inconsistency of the safety of GFE with the safety requirements of the overall system, the procuring NASA installation shall be promptly notified for appropriate action.

16. *Ground Support Equipment Safety.* The contractor shall design for safe operation of Safety Critical GSE. The contractor shall apply the system safety analysis approach of paragraphs 1D201-1 through 15 to Safety Critical GSE related to flight and test articles except program hardware handling equipment and walking and work platforms.

17. *Ground Handling Operations*

    a. The contractor shall assure that safe methods are implemented for ground handling and operations of the flight hardware, test hardware, and associated GSE to assure that the hardware is not damaged during ground handling and operations.

    b. The contractor shall comply with and submit a statement verifying the compliance with all of the Occupational Safety and Health Administration Standards, Part 1910, Sub-parts D, F, and N, for safety critical handling hardware and personnel walking and work platforms.

18. *Review of Changes.* When changes are proposed for equipment design or procedures, the contractor shall identify and resolve hazards that may be introduced into the system. Residual hazards shall be identified as part of the engineering change evaluation.

19. *Postflight Evaluation.* System safety shall participate in postflight reviews and a safety evaluation shall be made in cases where anomalous conditions are revealed. This safety evaluation will provide guidance in planning future missions and establishing necessary corrective action to reduce hazards.

1D202 INDUSTRIAL SAFETY

The contractor shall conduct Industrial Safety activities in compliance with the NASA Procurement Regulation identified in the General Provisions schedule. Industrial Safety includes identification, elimination, and/or control of hazards in employee and public accident prevention, fire prevention and protection, and transportation accident prevention at all the contractor's activities. The contractor's Industrial Safety/Occupational Health and Safety Plan shall consider elements such as:

1. Committees.
2. Training.
3. Certification.
4. Motivation.
5. Inspections and audits.
6. Control of unsafe conditions.
7. The design, construction, and activation of facilities.
8. The operation and maintenance of facilities.
9. Fire prevention and protection.
10. Handling and storage of hazardous materials.

11. Transportation.
12. Hazards to the public and employees, such as pollution and waste disposal, radiation, pesticides, noise and vibration, and explosion.
13. Accident investigation and reporting.
14. Hazardous operations.
15. Personnel protective equipment.
16. Contingencies, emergencies, and disasters.
17. Subcontractor Industrial Safety requirements and the methods employed to insure compliance.

1D203 TEST OPERATIONS SAFETY

1. *Margin of Safety Testing.* Provisions shall be made to assure that adequate validation tests are performed on critical devices or components to determine the degree of hazard or margin of safety of design. These types of tests will be specified in the Development and Verification requirements.
2. *Testing of Critical Equipment.* To protect personnel and avoid damage to test articles and facilities, the contractor shall review test plans for ground testing and flight testing of critical space flight type equipment to assure that tests are adequate to identify and assess potential flight hazards.
3. *Safety Monitoring.* Observation of designated hazardous tests/operations shall be accomplished as necessary to insure adherence to safety principles and compliance with safety requirements and checklists.
4. *Procedure Reviews.* Detailed test procedures and related documents for hazardous or high cost test/operations shall be reviewed and approved by the contractor's designated responsible safety personnel and subject to review by NASA. In the event the contractor places personnel in hyperbaric and altitude chambers or other similar type hazardous facilities, the procuring activity's safety requirements shall be met.

CHAPTER 3: RELIABILITY

1D300 RELIABILITY MANAGEMENT

The contractor shall maintain a reliability activity planned and developed in conjunction with other contractor elements. Reliability functions shall be an integral part of the design and development process and shall include the evaluation of hardware reliability through analysis, review, and assessment. Timely status reporting will be utilized to facilitate control of the reliability effort. Major elements of Reliability Management are:

1. *Organization.* The contractor shall be responsible for the planning, management, and effective execution of the reliability effort. The accomplishment of some reliability tasks may not be the responsibility of the reliability activity, but reliability shall monitor and ensure that the tasks are effectively accomplished.

2. *Reliability Plan*

   a. The contractor shall prepare and maintain a Reliability Plan which describes how the reliability requirements will be implemented and controlled. The plan shall be prepared in accordance with the applicable information requirements list/information requirement description (IRL/IRD).

   b. Reliability effort at each remote test site shall be governed by a self-contained separate section of the overall Reliability Plan or by a separate plan written for each site. The contractor shall identify those sites which require a separate plan.

3. *Reliability Audits.* The contractor shall conduct audits of the internal reliability activity and those activities of the suppliers. These reviews shall evalute progress and effectiveness and shall determine the need for adjustments or changes in the reliability activities. Audits shall be conducted at appropriate intervals.

4. *Reliability Progress Reporting.* The contractor shall report on the progress of the reliability effort through periodic management meetings.

5. *Supplier Control*

   a. The contractor shall ensure that the reliability of system elements obtained from subcontractors and suppliers meet the reliability requirements of the overall system. This applies to items obtained from any supplier whether in the first or any subsequent tier or whether the item is obtained by an intracompany order from any element of the contractor's parent organization. The contractor shall provide requirements, guidance, and controls to ensure the adequacy of subcontractor reliability implementation. The level of reliability requirements imposed on subcontractors and suppliers shall be appropriately tailored and identified to be consistent with those imposed on the prime contractor and shall include the state of hardware development and complexity, supplier experience, hardware unit cost, and hardware use.

   b. Where off-the-shelf hardware is anticipated, the contractor in the selection process shall examine historical data such as other contractor and program requirements and experience as well as reliability history, including failure mode and effect analysis (FMEA), maintainability, problem reporting and corrective action, electrical, electronic, and electromechanical (EEE) parts control, materials specifications and applications, test data (certification and acceptance testing), and design data. The results of this examination shall be documented and additional reliability controls, as appropriate, shall be applied.

6. ***Reliability of Government Furnished Equipment (GFE).*** **The contractor shall be responsible for the identification of the reliability data needed on GFE. Where examination of these data or testing by contractor indicates inconsistency of the reliability of GFE with the reliability requirements of the overall system, NASA shall be formally and promptly notified for appropriate action.**

1D301 RELIABILITY ENGINEERING

The contractor shall accomplish the following reliability engineering tasks on all flight equipment and as specified on flight GFE. The reliability engineering tasks to support the Chapter 2 safety requirement of assuring fail safe design and operation of GSE are limited to GSE used at or common to the launch-landing and retrieval sites and are identified in paragraphs 1D301-3, Failure Mode and Effects Analysis (FMEA) and Critical Items List (CIL), 1D301-4, Reliability-Maintainability Interface, 1D301-6, Problem Reporting and Corrective Action, and 1D301-7, Reporting and Resolving NASA Parts and Materials Problems (ALERTS).

1. ***Reliability Design Criteria.*** **Reliability design criteria for each subsystem shall be developed and utilized in the design and shall serve as a checklist to ensure compliance of the design to the criteria. The contractor's reliability effort shall include a system for the review and concurrence of design specifications and changes. The review shall ensure that the set of specifications covers all items of hardware and contains applicable reliability design criteria and requirements.**

2. ***Trade Studies.*** **The reliability effort shall include participation in design trades and shall utilize reliability numerical estimates as appropriate.**

3. ***Failure Mode and Effect Analysis (FMEA) and Critical Items List (CIL).*** **The contractor shall establish a system for the preparation, maintenance and control of FMEA's and CIL's.**

   a. **The contractor shall prepare design FMEA's at the lowest level of system definition required to support the potential uses (e.g., testing, failure reporting and corrective action, preparation of mandatory inspection points, etc.). FMEA's will be performed to the "black box" level and within the "black box" to pursue all critical functions. The identification of failure modes to the piece part level will be accomplished when these failure modes are criticality 1 or 2. The FMEA shall include an integration of all flight hardware, including flight GFE. The contractor effort shall include the necessary interface with the GFE contractors to ensure compatibility so that the integration can be accomplished effectively.**

   b. **Based on results of the FMEA's, CIL shall be prepared consisting of a single failure point summary (SFP) and a summary of redundant elements the failure of which could cause loss of life/vehicle or loss of mission where:**

      (1) **The redundant elements are not capable of checkout during the normal mission turnaround sequence; or**

      (2) **Loss of a redundant element is not readily detectable by the flight or ground crew; or**

      (3) **All redundant elements can be lost by a single credible cause or event such as contamination or explosion.**

   c. **Equipment appearing on the CIL will be given special attention in establishing hardware specifications and qualification requirements; in manufacturing, inspection and test planning; and in the formulation of operating and maintenance procedures and mission rules.**

   d. **The preparation of GSE FMEA's as applicable to 1D301-3a, -3b, and -3c, is limited to those functions containing failure modes which could cause criticality category 1 and 2 effects. The GSE FMEA and CIL tasks may be combined with the hazard analysis task to preclude duplication of analytical work and documentation. (Reference 1D201-4, Hazard Analysis.)**

4. *Reliability-Maintainability Interface*

a. The contractor shall provide reliability engineering inputs and participation in establishing maintainability criteria and plans to obtain maximum benefit from both design disciplines. Interfacing reliability tasks such as FMEA and redundancy studies shall be coordinated closely with corresponding maintainability trade-offs.

b. The contractor shall identify limited life items, including GFE specified by NASA, which require control from equipment date of manufacture throughout operational use, including storage. Provisions will be made for replacement or refurbishment of hardware after a specified age or operating time/cycle. The contractor shall report to NASA the status of limited life items and waivers on limited life items.

5. *Design Review and Readiness Review.* The Contractor's reliability activities shall include support of internal and supplier design reviews at the system, subsystem, and component levels and NASA design and readiness reviews. This activity shall include an assurance function for compliance of the design to the design criteria defined for the system, subsystem, and component levels. Each engineering change package shall contain a reliability assessment of the effect of the proposed change.

6. *Problem Reporting and Corrective Action.* The contractor shall provide a closed-loop system for the reporting of all problems (failures and unsatisfactory condition reports) and the establishment of corrective action for all problems concerning flight, test, simulator, and training hardware where that hardware is representative of flight hardware, GSE, applicable GFE, and spare hardware. The contractor shall be responsible for ensuring that problem reporting and corrective action systems of suppliers will meet the requirements of this section.

a. *Problem Reporting.* Reporting of problems shall be in accordance with the applicable IRL/IRD.

b. *Problems Analysis.* An analysis of each problem reported to NASA shall be performed to determine the cause of the problem and to implement adequate measures to prevent its recurrence. Primary emphasis shall be placed on hardware teardown analysis; however, where the cause of the problem is understood or where sufficient prior analysis experience has been obtained, additional hardware teardown for analysis may not be required.

c. *Problem Resolution.* The contractor shall resolve each problem by one of two methods: closeout or explanation. The contractor shall direct all efforts toward closing a problem in lieu of an explanation, and in no case shall the contractor attempt to "explain" a problem until it becomes impracticable to close the problem.

d. *GSE Problem Analysis and Resolution.* The GSE applicability of paragraph 1D301-6b and 6c is limited to GSE problems which could result in loss of vehicle systems or loss of personnel capability. Remedial or corrective action will be taken for the remaining GSE problems. Corrective action will be based on the following considerations:

(1) Vehicle flow or operational impact.

(2) Frequency of problem occurrence.

(3) Repair costs versus corrective action costs.

e. *Problem Status.* The contractor shall maintain a status on all open problems. The method(s) employed by the contractor in maintaining the status of problems shall be compatible to the contractor's needs as well as those of NASA in responding to requests for information. The contractor shall submit to NASA a listing of all open problems in accordance with the applicable IRL/IRD.

7. *Reporting and Resolving NASA Parts Materials Problems (ALERTS).* Problems with parts, materials, or equipment which are of mutual concern to NASA and associated contractors are reported by utilizing the NASA ALERT system (NASA Form 863). The contractor shall establish a

systematic approach to evaluate and respond to all NASA ALERTS and to investigate, resolve, and document parts and materials problems. Previously published ALERTS will be reviewed to assure that lots, batches, or other groupings of hardware noted as suspect in the ALERT are not used. A summary of previously published ALERTS will be provided by NASA.

a. *Investigation.* Upon receipt of a problem ALERT, the contractor will initiate an immediate investigation to determine the use significance of the problem item identified by the ALERT in its in-house program and in that of its subcontractors and suppliers.

b. *Resolution.* Subsequent to the start of acceptance tests when investigation discloses known or suspected usage of the problem item identified in the problem ALERT, a problem report will be issued against flight equipment having such usage and against GSE in which the failure of the ALERT item could cause loss of vehicle systems or loss of personnel capability. The reports will be prepared, resolved, and closed in conformance to the method defined in the Reliability Plan.

c. *Response.* The contractor shall provide a documented response on each ALERT investigation and resolution to NASA in accordance with the applicable IRL/IRD.

d. *Contractor-Initiated ALERTS.* When the contractor encounters a significant problem with a part or material which may adversely affect equipment, the contractor shall initiate an ALERT and submit it to the NASA ALERT coordinator. The contractor shall not release an ALERT on equipment without prior NASA approval.

8. *Electrical, Electronic, and Electromechanical (EEE) Parts and Mechanical Parts Control*

a. *General.* The contractor shall implement a system for controlling the selection, reduction in number of types, specification, application review, analyzing failures, stocking and handling methods, installation procedures, and establishing reliability requirements for EEE and mechanical parts to be used in contract and off-the-shelf hardware.

b. *EEE Parts Selection.* The contractor and suppliers shall select EEE parts for the contract hardware on the basis of suitability for their application(s) and proven qualifications of each to the requirements of its specification. Wherever practicable, items selected shall be already qualified to pertinent specifications, selection shall minimize the number of styles and generic types, and consideration shall be given to industry and Government preferred parts lists (e.g., MSFC document 85M03936). When selecting items previously qualified, the contractor shall devote particular attention to the currentness of data, applicability of basis of qualification, and adequacy of specifications. The results of the selection effort will determine requirements for additional qualification testing and will be the basis for the EEE parts list for the system. (See paragraph 1D301-8d.) The contractor is fully responsible for the satisfactory performance of each part regardless of the source from which the part was selected or who wrote or approved the controlling documentation.

c. *EEE Parts Specifications*

(1) Each EEE part shall be controlled by a specification (or combination of specifications) which delineates as a minimum: complete identification of the part; physical, environmental, and performance requirements; reliability requirements including inspections and tests for qualification, acceptance, and lot sampling where required; explicit requirements to be satisfied in accepting parts for use in the contract hardware including 100 percent screen and burn-in; packaging, storage, and handling requirements; traceability requirements; and data retention and submittal requirements.

(2) Where a combination of specifications is used collectively to provide all of the above requirements for a single part type, the detail specification (slash sheet, specification control drawing, etc.) for that part type shall provide detailed cross-reference to all other applicable specifications.

(3) Each specification shall be identified by a unique number, and all specifications shall be subject to a formal system of change control.

(4) All EEE parts specifications shall be available for NASA review upon request.

d. *EEE Parts Qualification*

(1) Qualification of EEE parts shall be at the part level to the requirements of the applicable specifications. Where adequate qualification data are not available (as determined jointly by the contractor and NASA), the contractor shall be responsible for the development and conduct of qualification tests on parts to determine their adequacy in meeting specification requirements and for the development of criteria to be used in acceptance testing. The contractor shall prepare test plans for those parts which it will subject to qualification testing.

(2) Requalification of parts shall be conducted as necessary to ensure continued control over design, materials, manufacturing processes, and quality controls after initial qualification.

(3) Qualification test plans and test reports shall be in accordance with the applicable IRL/IRD. In the event a part is used which deviates from this requirement, the contractor will submit a waiver request for the deviation.

(4) The contractor shall maintain a data file which identifies the basis and substantiates the status of qualification for each EEE part type used on the project. The file for each part type shall:

(a) Completely identify the part by generic part type and name, controlling specification name and number, common designation (closest commercial equivalent), and manufacturer's name and part number.

(b) Contain a summary of and provide cross-reference to all existing data used to substantiate the qualification of the part to the controlling specification. When the basis of qualification is similar to an already qualified part, complete identification and supporting data for the similar part shall be included together with the analysis that establishes similarity.

e. *EEE Parts List and Where-Used Parts Lists.* The contractor and suppliers shall prepare and maintain a project EEE parts list and composite where-used parts list in accordance with the applicable IRL/IRD.

f. *EEE Parts Application Review.* The contractor (or supplier, if appropriate) shall conduct thorough parts application reviews on the design of each component (black box) at appropriate milestones during its design and development. The results of these reviews will be an input to the design reviews. (See paragraph 1D301-5.) The application of each part shall be examined in light of its rated capabilities in comparison to the design requirements of that application and conformance to the established derating criteria. The derating criteria shall, as a minimum, require a 25 percent derating of upper worst case thermal and electrical stress levels from the part specification maximum rating. The application review shall ensure that the part will not be stressed in excess of its lower temperature or upper mechanical stress levels as established through part qualification. Consideration shall be given to anticipated life requirements, functional and environmental usage stresses, and historic and current failure experience (i.e., results of analyses of parts failures which have occurred in higher level assemblies on the same system or other projects). Special attention shall be given to any parts used which are not selected from the projects parts list, and the review output documentation shall include or refer to justification for each such usage. The contractor shall take immediate action to correct identified deficiencies.

g. *EEE Parts Handling and Traceability*

(1) The contractor shall specify minimum requirements for control of storage, stocking, and installation procedures for parts. These controls shall prevent use of parts which may be in a questionable condition and prevent degradation of parts due to environments or faulty manufacturing or assembly techniques.

(2) The contractor shall assure that backward traceability data can be provided for all EEE parts. (See paragraph 1D502.) Provisions shall be made to record and retrieve information relating to the specific tests performed, test results, and processes on each lot of parts. Identification of the part manufacturer's production, assembly, or test lot shall be available for each part installed in deliverable end items including qualification and test articles.

h. *EEE Parts Problem Reporting and Corrective Action.* The contractor shall investigate the cause of each part failure and determine remedial and preventive action. The significance of the failure as related to like parts or materials used elsewhere in the system and the possibility of the occurrence of additional failures shall be determined and documented as part of the problem disposition in accordance with paragraph 1D301-6, Problem Reporting and Corrective Action.

i. *EEE Parts Deviations and Substitutions.* The contractor shall establish and maintain an adequate system to monitor and control the use of deviated and substituted parts in contractor, subcontractor, and supplier equipment at all levels of procurement, test, and fabrication. The system shall provide for the prompt identification, reporting, review, and approval/disapproval disposition of the deviated or substituted parts. The provisions of this paragraph will be invoked when EEE parts do not conform to paragraph 1D301-8c, Parts Specification, and paragraph 1D301-8d, EEE Parts Qualification. (See Glossary of Terms for definitions.) Subsequent to the CDR, all requests for EEE part changes, deviations, or substitutions shall be submitted to NASA for approval.

j. *EEE Parts Control for Off-the-shelf Equipment*

(1) EEE parts used in off-the-shelf equipment shall conform to the requirements of paragraphs 1D301-8c and 8d. A where-used parts list in accordance with paragraph 1D301-8e is required. A parts application review in accordance with paragraph 1D301-8f must be accomplished and must assess the adequacy of each part in each application and assure compliance with any applicable NASA restriction on specific parts usage or application. The requirements of paragraph 1D301-8g apply to any new manufacture of equipment to an existing design.

(2) Problem reporting and corrective action in accordance with paragraph 1D301-8h and control of substitutions and deviations in accordance with paragraph 1D301-8i are required.

k. *Mechanical Parts.* MIL-STD 143, "Standards and Specifications, Order of Precedence for the Selection of," shall apply in selecting specifications for standard mechanical parts. Rationale for the selection of company specifications and standards over existing higher order of precedent standards and specifications shall be made available to the procuring activity upon request. This rationale shall include an identification of each higher order of precedent specification or standard examined and state why each was unacceptable.

9. *Materials Specifications and Application Reviews*

a. *Materials Specifications.* The contractor shall review design specifications to determine compliance with all required materials specifications. These specifications shall constitute the basis for description and control of all materials to be used in the contract hardware. Where adequate specifications do not exist (as determined jointly by the contractor and NASA), the contractor shall make appropriate recommendations to NASA.

b. *Materials Application Reviews.* The contractor shall review all materials applications for compliance with flammability and material specifications. The contractor (or supplier, if appropriate) shall conduct thorough materials application reviews on the design of each component (black box) at appropriate milestones during its design and development. Consideration shall be given to anticipated life requirements, functional and environmental usage stresses, and historic and current failure experience (i.e., results of analysis of materials failures which have occurred in higher level assemblies on the same system or project). Special attention shall be given to the continuous review and assessment of flammability and off-gassing properties of materials. This shall include, but not be limited to, material usage, status, test, evaluation, substitution, and verification. The results of these reviews will be an input to the design reviews. (See paragraph 1D301-5, Design Review and Readiness Review.)

1D302 TESTING

The contractor shall participate in the conduct of the certification and acceptance test program as follows:

1. *Certification:* The contractor shall monitor and support the certification program established to demonstrate that the design of hardware is capable of meeting its requirements. The contractor shall assure that adequate documentation is maintained to substantiate and track activities in meeting certification requirements imposed by contract.
2. *Acceptance Testing:* The contractor shall review all acceptance test requirements to assure that they are adequate for performance verification and to detect manufacturing defects.

CHAPTER 4: MAINTAINABILITY ASSURANCE

1D400 MANAGEMENT

The Contractor shall provide this design assurance discipline in conjunction with reliability during all program phases with the major effort concentrated in the design phase. The Contractor's maintainability program shall consider all pertinent operations and missions requirements and be closely integrated with the maintenance engineering service and support function. The Contractor shall prepare a Maintainability Plan which describes how the program will be accomplished, including necessary participation of subcontractors and suppliers. The plan shall be prepared and submitted in accordance with the applicable IRL/IRD.

1D401 PROGRAM ELEMENTS

The maintainability program shall include the elements described below as a minimum.

1. *Maintainability Parameters.* Establish measurable parameters such as mean time to repair, fault detection/isolation capability and maintenance staffhours per turnaround considering turnaround/reaction time requirements, limited life items (see par 1D301-4a) maintenance resources, and other factors.
2. *Maintainability Allocation.* Budget parameters to system/subsystem/equipment and establish criteria to meet targets.
3. *Maintainability Analysis.* Evaluate proposed designs and provide maintainability predictions in a timely manner so as to influence designs without costly changes. Conduct trade-off studies considering maintainability versus such elements as cost, weight and reliability. Provide inputs to design and to logistics and maintenance planning.
4. *Design Reviews.* Conduct in-house and supplier reviews and support NASA reviews to assure the maintainability features of the developing designs are optimized.
5. *Maintainability Data.* As maintainability data on hardware become available from supplier and in-house developments and operations, collect, analyze and compare with established maintainability targets. Feedback to design for corrective action the critical maintainability areas disclosed.
6. *Verification and Demonstration.* Through analyses and practical demonstrations on mock-ups and early flight hardware, verify the achievement of design maintainability requirements.
7. *Maintenance Data.* When operational experience becomes available, these data shall be collected and analyzed and compared to allocations and predictions. Where discrepancies exist, corrective action shall be initiated and the results reported to NASA.

CHAPTER 5: QUALITY ASSURANCE

1D500 MANAGEMENT AND PLANNING

1. *Planning.* The contractor shall maintain an effective and timely quality assurance activity planned and developed in conjunction with all other contractor's functions necessary to satisfy the contract requirements. The activity shall:

   a. Demonstrate recognition of the quality aspects of the contract and an organized approach to achieve them.

   b. Ensure that quality requirements are implemented and satisfied throughout all phases of contract performance, including preliminary and engineering design, development, fabrication, processing, assembly, inspection, test, checkout, packaging, shipping, storage, maintenance, field use, flight preparations, flight operations, and post-flight analysis, as applicable.

   c. Ensure that quality aspects are fully included in all designs and are continuously maintained in the fabricated articles and during operations.

   d. Provide for the detection, documentation, and analysis of actual and potential deficiencies, system incompatibilities, marginal quality, and trends or conditions which could result in unsatisfactory quality.

   e. Provide timely, effective documented remedial and preventive action.

2. *Organization.* The contractor shall ensure that the effectiveness of quality functions and the ability of assigned personnel to objectively assess, document, and report findings is not hampered by other considerations (such as the overt influence of engineering changes, rework, or rescheduling) during all phases of the contract work. The contractor shall designate one individual who shall have the responsibility and authority for directing and managing the quality activity. That individual shall have direct, unimpeded access to the management level having full responsibility for the contract work and shall report regularly to higher management on the status and adequacy of the quality activities.

3. *Quality Plan.* The contractor shall prepare, maintain, and implement a Quality Plan which describes how he/she will ensure compliance with the requirements set forth herein. The plan shall be submitted as specific in the applicable IRL/IRD. The plan content shall be readily identifiable with each cited requirement and shall cover all quality activities for the contract. Contractor policies and procedures which implement these requirements shall be identified. The contractor shall use existing policies and procedures to the maximum extent. New procedures should only be developed for the unique requirements of a cost-effective system, such as the use of designees (see par 1D505-9) or certification of suppliers' quality systems. Procedures which define Government involvement shall be reviewed and approved by NASA. New or existing policies and procedures which contain no Government involvement shall be available for NASA review. Changes to the plan shall be in accordance with instructions specified in applicable IRL/IRD. The plan shall serve as the master planning and control document. Separate Quality Plans, or a plan with separate sections shall be prepared for the contractor's activities at the plant site and at each remote test site.

4. *Quality Controls.* The contractor shall develop effective management control of the quality effort. The contractor shall identify how its quality tasks will be implemented for both contractor and supplier hardware within the scope of the basic quality tasks. The quality requirements implemented

shall be tailored to include the state-of-hardware development, contractor experience, hardware unit cost, complexity, and hardware use.

5. *Nondestructive Evaluation.* The contractor shall integrate the definition, assessment, validation, and application, including sequence of operation, of NDE (nondestructive evaluation) methods, to meet design, development, production, and test requirements of the Shuttle program. Provisions for NDE shall be optimized for the operational requirements. For critical components and structures, quantitative accept/reject criteria shall be established to enable selection of validated NDE methods capable of detecting incipient flaws and variations in material properties. When assessment of NDE capability indicates the desired capability cannot be obtained utilizing "state-of-the-art" NDE, alternate design or fabrication techniques shall be considered. If these changes cannot satisfy the desired evaluation capability, the contractor will perform additional validation tests or identify the supporting research and technology needed to either develop new or extend existing NDE methods.

6. *Management Assessment Data.* The contractor shall present the quality status at periodic meetings with NASA. The meetings should cover significant accomplishments, potential management and hardware problems, recommendations, summary of remedial and preventive actions, quality costs, and presentation of pertinent data. Pertinent data shall include scrap rates, frequencies of repairs and trend charts by end item, discrepancies which indicate totals as well as their relation to special processes (e.g., wiring, contamination, etc.). The contractor's system shall allow the identification of costs of both prevention and correction of nonconforming supplies (e.g., labor and material, when available, involved in material spoilage caused by defective work, correction of defective work, and for quality control exercised by the contractor at subcontractors' or vendors' facilities). These data shall be included for selected subcontractors and suppliers. The data shall be submitted in accordance with the applicable IRL/IRD.

7. *Training*

   a. *Planning.* The contractor shall develop, maintain, and implement necessary quality training. Training activities shall be documented and shall provide for:

      (1) Excellence of workmanship and personnel skills.

      (2) Careful and safe operations.

      (3) Maintenance and improvement, where necessary, of article and material quality.

      The training for critical processes (refer to the Glossary of Terms) shall include, as applicable, adhesive and resin application, welding, brazing, soldering, electrical connector operations, contamination control operations, and nondestructive testing evaluations. The contractor shall utilize the list of critical processes (refer to paragraph 1D504-4C) to develop training requirements.

   b. *Certification of Personnel.* Contractor personnel controlling critical processes and personnel performing critical operations shall be certified. Certification shall include satisfactory completion of a NASA approved written examination and/or a performance demonstration which may be repeated by NASA, or its designated representative, to verify the adequacy of such certification. Personnel certified by the contractor shall be given a card, badge, or similar evidence of certification to be carried on their person while performing their duties.

   c. *Recertification of Personnel.* Contractor personnel shall be recertified based on contractor or Government observation of unsatisfactory quality of articles or services; changes in techniques, parameters, or required skills; or interruption of work period as established for the process or operation involved. Recertification shall require retesting of the individual to the testing procedure to demonstrate continuing proficiency. Persons failing the retest shall not be permitted to perform these processes or operations until provided with additional training and required proficiency has been demonstrated.

   d. *Records.* Records shall be maintained of the training, testing, and certification status of personnel.

8. *Quality Program Audits*

a. *General.* The contractor shall conduct audits of personnel, procedures, and operations which implement the quality program. Each audit shall be performed by a team of contractor personnel familiar with all written procedures and standards applicable to the operation or work areas being audited and shall include personnel not having specific line responsibilities in those areas. Each audit shall include examination of all operations and documentation, evaluation of actual operations as compared with established requirements, recommendations for remedial and preventive action, and followup to assess results of recommendations. Audits shall include examination of articles and materials to verify the effectiveness of the contractor's efforts.

b. *Audit Schedule.* Random unscheduled audits shall be performed in order to effectively assess existing conditions and operations. Audits are to be conducted on a random basis, but provisions shall exist to ensure that each quality area is audited.

c. *Audit Reports.* The results of audits in each area shall be documented in a report to contractor higher management with appropriate recommendations for correction of deficiencies. Management action shall be taken to ensure effective correction of the reported deficiencies. Followup reviews shall be made to ensure that required corrections have been implemented.

1D501 DESIGN AND DEVELOPMENT CONTROLS

1. *Technical Documents*

a. The contractor shall establish, document, and ensure compliance with design control requirements and quality criteria during all phases of contract work. The contractor shall ensure enclusion of quality characteristics and design criteria necessary for procurement, fabrication (including assembly), inspection and test operations, and post-flight operations (including inspection, test, refurbishment, and prelaunch checkout), as applicable in specifications, procedures, drawings, and fabrication and planning documents.

b. The contractor shall utilize a system which identifies hardware characteristics requiring verification. This identification should be based on the use of the hardware involved and shall be utilized in developing quality inspection and test surveillance planning, as an input to the development of Inspection Points, and in the development of quality criteria, workmanship and inspection standards, and inspection procedures.

c. Contractor quality assurance personnel shall conduct a timely review of technical documents that affect quality and changes thereto. Reviews shall ensure that all necessary information has been included and that requirements are clear and unambiguous. The reviews shall be documented and action shall be taken to ensure correction of deficiencies. These reviews shall also be an integral part of the quality planning function to ensure timely planning of quality activities and facilities associated with subsequent procurement, fabrication, assembly, inspection, testing, delivery, post-flight inspections and tests, and refurbishment activities.

2. *Quality Support to Design Reviews*

The contractor's quality activity shall include participation in design reviews to ensure that designs permit and facilitate productivity, repeatability, inspectability, refurbishability/maintainability and that related quality considerations are well defined. Quality design criteria shall be developed and utilized in the design and shall serve as a checklist during the design reviews to assure compliance with the criteria. Participation in review activities shall be documented to provide a historical record of quality performance and subsequent concurrence with design development as noted below:

a. *Contractor Internal Design Reviews.* In implementing quality requirements, the contractor's quality activity shall assure that the program documentation (drawings, specifications, technical documents) includes, as a minimum:

(1) Identification and data retrieval requirements (par 1D502);

(2) Identification of critical hardware characteristics necessary for procurement and fabrication (including assembly, inspection, and test operations);

(3) Inspection and test criteria (including specific NDE methods, test equipment, environmental conditions, and sample size, as applicable);

(4) Performance and/or tolerance limits;

(5) Applicable specifications for contamination control;

(6) Applicable process specifications, standards, and procedures;

(7) Limited life items; and

(8) Acceptance/rejection criteria.

b. *Design Reviews (PRR, PDR, CDR, etc.).* The contractor's quality activity shall participate in review of selected program documentation prior to submittal to NASA and ensure the following:

(1) Repeatability and inspectability of the selected design approach by determining the special inspection and testing tools, equipment, and facilities required;

(2) Characteristics which influence quality are within inspection "state-of-the-art" capabilities;

(3) Criteria to judge conformance to these characteristics have been established;

(4) Quality controls at interfaces are noted adequately in the interface control documents;

(5) Process specifications and quality controls have been adequately defined;

(6) Design criteria and procedural standards have been considered; and

(7) Acceptance test specifications contain adequate acceptance/rejection criteria.

c. *Acceptance Reviews.* The contractor shall ensure that the following are accomplished in support of the acceptance reviews:

(1) Evaluation of test and checkout operations and results with discussion of anomalies encountered, failure history, and remedial and preventive actions; status of all open tests with an identification of those that constrain further activities, such as flight mission.

(2) Identification of waivers and deviations to specifications and verify basis for approval.

(3) Status of limited life components and their remaining life.

(4) Identification of shortages, open work items, and related corrective actions.

(5) Status of open work items (to be accomplished).

(6) Development of a form DD250 indicating shortages and deficiencies which must be resolved prior to further activities, such as flight readiness.

(7) Verification that departures from specifications and drawing requirements have been processed in accordance with paragraph 1D506.

(8) Verification that all data packages and support manuals for the operation, checkout, and maintenance of the end-item are complete, compatible and accompanying the hardware, and that all shipping requirements of this document have been met.

3. *Change Control*

a. The contractor shall be responsible for control of quality generated documents and changes thereto. Documents affecting quality shall be distributed to the proper control locations at the proper times and obsolete documents removed from the system. All engineering changes shall

be reviewed to determine quality impact. Necessary interfaces with program management, data management, and configuration control functions shall be provided in order to define and facilitate reporting directly to top management any quality impact due to program documentation changes.

b. The contractor shall be responsible for coordination of engineering changes affecting the quality activity between both contractor and subcontractor quality activities to ensure proper and timely assessment of any quality impact.

c. The contractor shall verify that the effectivity point of documents and changes which affect materials, fabrication or quality is clearly identified. The contractor shall verify that changes are accomplished on the affected articles or materials at the authorized point; changed articles are appropriately marked or identified; and associated documents are revised accordingly. Provisions shall be made for inspection and test of changed articles or materials.

1D502 IDENTIFICATION AND DATA RETRIEVAL

1. *General.* The contractor shall develop and maintain a systematic technique of documented identification and data retrieval for articles and materials to provide:

   a. Identification to which procurement, fabrication, processing, inspection, test, and operating records can be related; and

   b. Means for locating articles and materials.

   The contractor technique shall be developed in conjunction with other contractor systems, such as engineering documentation control, configuration management and logistics management. Common identification numbers and procedures shall be used among all systems. The data requirements may be implemented by use of a manual data and record system, or a mechanized system may be used in lieu of, or in support of, a manual system.

2. *Identification and Data Retrieval Requirements.* Selected items based on design complexity, application, performance characteristics, manufacturing, processing or environmental conditions, and limited life sensitivity shall be subjected to identification and data retrieval requirements. These items (including components and parts along with connecting lines and/or tubes) shall have detailed identification to their origin, e.g., manufacturer, materials, manufacturing date, purchased lot, inspection or test data, or other pertinent information. Identification and data retrieval requirements shall be established for electronic, electrical, and electromechanical parts which will provide the capability of tracing backwards from fabricated hardware to the records required in par. 1D502-5. Provisions shall be made to record and retrieve information relating to the specific test performed, test results, and processes on each lot of parts. Equipment with identification and data retrieval requirements shall automatically require identification and data retrieval through all higher levels of assembly.

3. *Identification Methods.* Each article and material shall be identified by a unique part or type number. Where control of individual articles, lots of articles, or materials is required, one or more of the following detailed identification methods shall be used, as applicable:

   a. *Date Codes.* Date codes indicating date of manufacture to identify articles or materials made by a continuous and controlled process and those which are subject to variations on degradation with age.

   b. *Lot Numbers.* Lot numbers to identify articles or materials produced in homogenous groups and where unique data are not required to be related to individual items. Heat, billet, or batch numbers are included in this category.

   c. *Serial Numbers.* Serial numbers to identify individual materials or articles for which unique data are to be maintained or when other reasons exist for individual control.

d. *Other Identification.* Other identification methods, such as paint dots in lieu of or in addition to the methods specified herein, upon approval of the designated Government quality representative.

4. *Documentation.* Methods and location of part or type numbers and detailed identification on articles and materials shall be indicated in technical documents.

5. *Identification Control.* Controls shall be established to ensure that detailed identification numbers for individual articles and materials or lots thereof are assigned in a consecutive manner. Records for articles and materials shall indicate applicable part or type numbers and associated detailed identification. This shall provide the capability of tracing backward to the material from which fabrication originated and to determine the location of the like articles or materials within a level of process or assembly. Serial or lot numbers of scrapped articles or materials shall not be used for other similar articles or materials. Temporarily installed items shall be clearly identified to permit easy location and rapid removal after use.

6. *Record Retrieval.* Contractor identification systems shall ensure that article and material procurement, fabrication, processing, inspection, and test records are related to the applicable articles and materials. It shall be organized so that these records and the related articles and materials may be located and retrieved in the event verification of, or removal of, articles and materials becomes necessary. If required, complete data and record retrieval and analysis should be accomplished within a reasonable period based on the urgency of the problem.

7. *Retention of Records.* Records of articles and materials which have been designated for identification and data retrieval shall be retained in a safe, accessible location by the contractor for the period specified in the contract, unless released prior to the time by contractual authorization. The contractor shall also invoke this same requirement on the subcontractors and suppliers. The prime contractor shall be responsible for assuring that applicable records are not destroyed, unless authorized by the contracting officer.

D503 PROCUREMENT

1. *Procurement Controls.* The contractor shall assure the adequacy and quality of all contractor-purchased articles, materials, and services. The contractor shall plan, implement, and maintain procurement quality activity to ensure timely and adequate integration with all other elements of the organization (design, procurement, etc.) having responsibility for control and performance of subcontractor/suppliers (hereinafter designated procurement sources). The responsibility for ensuring overall planning and implementation of quality assurance functions at all procurement sources shall be assigned to one clearly identified group within the contractor's quality organization. The activity shall provide for long-range and detailed planning, total visibility of all procurement quality activities, functional integration within the contractor organization, and effective performance at all levels of procurement, including subtier sources and other divisions or subsidiaries of the contractor. Functional responsibility shall include, but not be limited to, the following:

   a. Participate in selection of qualified procurement sources.

   b. Develop quality requirements for each procurement source.

   c. Review and/or approve selected procurement documents including, as minimum, those for flight hardware and the fail safe requirements of GSE.

   d. Ensure that procurement documents refer to specific items requiring identification and data retrieval.

   e. Provide technical assistance and training to procurement sources when necessary to achieve desired quality levels.

   f. Approve procurement source quality and/or inspection systems.

   g. Provide resident or itinerant quality control representatives as required.

h. Monitor, survey, and assess procurement source quality performance including staffing practices.

2. *Selection of Contractor Procurement Sources.* Contractor quality personnel shall participate in the selection of procurement sources. The contractor's evaluation and selection shall be based on one of the following:

a. The procurement source shall have a previous and continuing record of supplying quality articles, materials, or services of the type being procured. The record shall be supported by qualitative and quantitative documentation.

b. A pre-award survey of the procurement source facility and quality system shall be conducted in accordance with documented contractor procedures to determine if the procurement source is capable of satisfying procurement quality requirements. The results of pre-award surveys shall be documented and maintained on file by the contractor.

c. When articles or materials are not fabricated specifically for contracts or subcontracts issued under NASA contracts, a pre-award survey of the source is not required. In such cases, a thorough inspection of the articles and materials shall be performed in accordance with technical documents.

3. *Procurement Documents*

a. *Review.* Selected procurement documents that are issued at contractor plant sites and facilities, including other divisions or subsidiaries of the contractor, shall be reviewed by quality personnel prior to release for adequacy of quality requirements. Such reviews shall be documented and shall include determination that:

(1) Procurement sources have been selected in accordance with paragraph 1D503-2; and

(2) Applicable provisions of paragraph 1D503-3b have been properly cited.

b. *Contents.* Procurement documents shall contain provisions for the following:

(1) *Procurement Source Quality Activity.* Each procurement source and its subtier sources shall be required to comply with one of the following:

(a) Subcontracts for procurement of systems, subsystems, and related services shall invoke this document or applicable portions thereof.

(b) All other suppliers except those of off-the-shelf hardware shall be required to follow the applicable provisions of this section and/or NASA publication NHB 5300.4(1C). The contractor, in complying with these requirements, may use the existing procurement requirements document(s) as identified in the Quality Plan. Approval by NASA shall be required prior to implementation. For off-the-shelf hardware suppliers, historical data shall be examined and assessed to determine the appropriate quality controls to be applied. The requirements for each procurement shall be tailored to include only the necessary requirements based primarily on the state-of-the-hardware development, the contractor experience, hardware unit cost, and the use of the part, component, subsystem, or system.

(2) *Basic Technical Requirements.* Procurement documents shall specify or refer to technical requirements for articles, materials, or services to be provided by a procurement source. Applicable revisions shall also be indicated and documents provided.

(3) *Detailed Quality Requirements.* The following detailed quality requirements, as necessary, shall be additionally included or technical documents containing these requirements shall be referred to. Applicable revisions of referenced documents shall be indicated and documents provided as necessary to the procurement source.

(a) *Changes.* The procurement source shall be required to notify the contractor of any proposed changes in design, fabrication methods, or processes approved by the contractor, including changes which may affect the quality or intended end-use of the item, and obtain written approval of the change from the contractor before making the change. Changed articles shall be identified differently from previous articles. When a proprietary item is procured by the contractor, the procurement source shall be required to notify the contractor of changes in its design, fabrication methods or processes.

(b) *Purchased Raw Materials.* Purchased raw materials shall be accompanied with chemical and/or physical test results.

(c) *Raw Materials Used in Purchased Articles.* Tests performed on specimens or detailed analyses of procurement source acceptance test results on all raw materials that are required to satisfy specification requirements and which are employed in the fabrication of articles purchased on this subcontract or purchase order shall be made available to the contractor upon request.

(d) *Preservation, Packaging, Packing, and Shipping.* Requirements for preservation, packaging, packing, and shipping of articles and materials shall be specified or referenced.

(e) *Age Control and Life Limited Products.* Records for articles and materials having definite characteristics of quality degradation or drift with age and/or use shall indicate the date and test time or cycle at which useful life was initiated, the life or cycles used, and the date and test time or cycle at which useful life will be expended. When appropriate, specify that the articles and materials exhibit similar information. The procurement source shall ensure removal or rework of such articles and materials are required.

(f) *Identification and Data Retrieval.* Identification and data retrieval requirements shall be specified.

(g) *Inspection and Test Characteristics.* Characteristics to be subjected to inspections or tests by the procurement source shall be specified.

(h) *Inspection and Test Records.* Inspection and test records to be maintained by the procurement source to provide evidence of inspections and tests shall be clearly specified. Records to be provided to the contractor or source inspection personnel shall be specified.

(i) *Resubmission of Nonconforming Articles or Materials.* Nonconforming articles and materials returned to the procurement source by the contractor and subsequently resubmitted by the procurement source to the contractor shall bear adequate identification of such resubmission either on the article or material or on procurement source records. Reference shall be made to the contractor's nonconformance document and evidence provided that causes for nonconformances have been corrected and actions taken to preclude recurrence.

(j) *Contractor Quality Assurance Activity at Source.* When contractor quality assurance activity is required at source, the procurement document shall so indicate.

(k) *GSI (Government Source Inspection).* When the Government elects to perform inspection at a procurement source, the following statement shall be included in the procurement document:

"All work on this order is subject to inspection and test by the Government at any time and place. The Government quality representative who has been delegated NASA quality assurance functions on this procurement shall be notified immediately upon

receipt of this order. The Government representative shall also be notified 48 hours in advance of the time articles or materials are ready for inspection or test."

(l) *Procurements Other Than Those Requiring GSI.* Procurements which do not require Government Source Inspection shall include the following statement:

"The Government has the right to inspect any or all of the work included in this order at the supplier's plant."

(m) *Procurement Source Data Package.* The total data package requirements of the supplied item, including equipment record and historical data requirements, shall be specified. These requirements shall be adequate to satisfy acceptance of the supplied item as well as satisfy the applicable data requirements for the end-item as specified in the applicable IRL/IRD.

(n) *Process Specifications of Procurement Sources.* A listing of critical processes shall be specified as defined in the applicable IRL/IRD.

(o) *Pressure Vessel Historical Data Requirements.* Historical data maintenance on each pressure vessel shall be in accordance with the IRL/IRD. The data shall be maintained and compiled for inclusion into the acceptance data package, as applicable.

(p) *Cleanliness Control.* Detailed cleanliness control shall be specified as applicable.

(q) *Ordnance Data Requirements.* Data maintenance on each ordnance device shall be in accordance with the applicable IRL/IRD. The data shall be maintained and compiled for inclusion into the acceptance data package and to support lot flight certification.

4. *Contractor Quality Assurance Personnel at Source*

a. *Planning.* The contractor may assign resident or itinerant quality assurance personnel at subcontractor or supplier facilities. The contractor quality assurance source inspection staffing policy shall be clearly described in the Quality Plan. Assigned representatives will implement control through planned documentation which details specific requirements and facilitates the recording of corrective action, periodic surveys and other information necessary to ensure that the subcontractor or supplier complies with applicable requirements. Assignment of quality personnel shall be based on the use of the equipment, the hardware unit cost, the contractor's experience with the source or when one or more of the following exists:

(1) In-process or end-item controls have such an effect on the articles that the quality cannot be determined solely by inspection or tests of the procured articles at the contractor's plant; or

(2) Verification tests are destructive in nature and the quality cannot be verified solely by inspections or tests at the contractor's plant; or

(3) The environments or test equipment required cannot be feasibly and economically simulated or made available at the contractor's plant; or

(4) Past performance or quality history of the subcontractor or supplier is marginal; or

(5) Qualification testing is to be performed by other than the prime contractor or major suppliers; or

(6) Articles or materials are designated for direct shipment from source to NASA or the using site.

b. *Task Assignment.* The contractor shall provide a list of duties, responsibilities, and authorities of the assigned quality assurance personnel to the designated Government quality representative at contractor's facility. When both Government Source Inspection personnel and contractor personnel are utilized at a supplier facility, the list shall also be provided to the Government quality representative at the supplier's facility upon issuance of the procurement document.

c. *Interrelated Source Activities.* The contractor should organize its source activities so that the services of the assigned contractor quality assurance source representative can be made available to other contractors and subcontractors participating in the Space Shuttle program. Affected contractors shall mutually determine the extent of responsibility and authority to be assigned for execution of all interrelated quality assurance activities to achieve maximum proficiency without redundant performance.

5. *Government Source Inspection.* Source inspection performed by and for the convenience of the Government on procured articles or materials shall not, in any way, replace contractor source inspection or relieve the contractor of the responsibilities for ensuring product quality. The contractor shall process procurement documents through the designated Government quality representative for determination of the need for Government Source Inspection.

6. *Receiving Inspection.* The contractor shall maintain a documented receiving inspection system which ensures:

a. That procured articles and materials indicate evidence of inspections and tests performed by the procurement source in accordance with purchase requirements and are accompanied with required inspection and test data.

b. That articles and materials or accompanying records exhibit evidence of contractor and Government Source Inspection, as required.

c. That procurement source inspection and test data are acceptable by conducting inspections and tests of selected characteristics. As a minimum, receiving inspection and test shall include verification of characteristics and design criteria which have not been source inspected by the contractor and which can be verified without disassembly of the article. Particular emphasis shall be placed on those characteristics for which nonconformances may not be detected during subsequent inspections and tests.

d. That periodic disassembly is accomplished as appropriate for more detailed verification of the specified requirements.

e. That identification and data retrieval requirements have been met and are maintained; that all required data and records are complete and correct; and that articles and materials can be directly related to applicable procurement source records.

f. That appropriate inspection and test equipment and technical documents are available at the proper places and at the proper times to perform the test and inspections.

g. That procurement source records for articles and materials having definite characteristics of quality degradation or drift with age and/or use indicate the date and test time or cycle at which useful life was initiated, the life or cycles used, and the date and test time or cycle at which useful life will be expended. The records shall be maintained and updated if life or cycle use occurs during receiving inspection activities. The receiving inspection system shall also ensure that the articles and materials, when required, exhibit evidence of initiation of useful life, the life or cycles used, and the date and test time or cycle at which useful life will be expended.

h. When required by specification or drawing, chemical analyses and physical tests are performed on test specimens submitted with purchased articles and materials.

i. That chemical analyses and physical tests are conducted according to the established inspection and/or sampling plan.

j. That the inspection status of articles and materials is maintained during receiving inspection and test operations. This shall include physical separation and identification of articles and materials according to the following categories:

(1) Items awaiting inspection or test results.

(2) Conforming items.

(3) Nonconforming items.

k. That articles and materials and their records clearly indicate their acceptance or nonconformance status when released from receiving inspection and test.

l. That articles and materials to be released are adequately controlled and protected for subsequent handling, storage, or use.

7. *Receiving Records.* Receiving inspections and test records shall be maintained for articles and materials to indicate, as a minimum, date of receipt, accomplishment of applicable requirements of paragraphs 1D503-6a through l, results of inspections and tests, inspection and test procedures utilized, and disposition of the articles or materials. Records shall include copies of pertinent procurement source documents received or an indication of the type of documents received and their location.

8. *Procurement Source Data.* Receiving inspection and test results shall be recorded to reflect on a continuous basis the qualitative and quantitative performance of individual sources and the quality histories of the supplied articles and materials. The contractor shall maintain data to aid in the selection of procurement sources based upon these results.

9. *Post-Award Survey of Procurement Source Operations*

a. *General.* The contractor shall schedule and conduct post-award surveys of procurement sources based upon:

(1) Type of items being procured.

(2) Known problems or difficulties.

(3) Procurement source quality history.

(4) Fabrication and testing capability.

(5) Remaining period of procurement source performance.

b. *Planning.* A schedule shall be prepared in matrix form and shall include all planned surveys for at least one year in advance. The schedule shall be maintained throughout the duration of the contract.

c. *Classification.* The following types of surveys shall be scheduled when applicable:

(1) *Premanufacturing Survey.* Assurance shall be obtained that there is a complete understanding among all parties concerning all contract requirements and that the procurement source is capable of producing a quality product.

(2) *Predelivery Survey.* Assurance shall be obtained that the first unit to be delivered is a compliance with all contract requirements and that all the following units will be identical to the first.

(3) *Quality Maintenance Survey.* Assurance shall be obtained that the procurement source is maintaining an effective quality system. A quality maintenance survey shall be conducted at least annually on major suppliers. Surveys of all other suppliers will be as required.

d. *Reporting.* A summary of survey results shall be documented, including problem areas discovered, with recommendations for timely correction and prevention of deficiencies; also, recommendations for followup action.

e. *Unified Survey Activities.* The contractor shall establish a joint survey program with other affected Space Shuttle contractors to minimize the number of post-award surveys performed at sources of common hardware. A joint survey planning committee comprised of representatives from each major contractor shall define a baseline for survey planning, performance, reporting, and followup. Procedures shall be established and documented for administering this effort.

10. *Coordination of Contractor Procurement Source Inspections and Tests.* The contractor shall coordinate with selected sources to ensure compatibility of procurement source inspections and

tests with contractor inspections and tests of the procured article or material. The contractor shall provide technical assistance and training for procurement sources as necessary.

1D504 FABRICATION CONTROLS

1. *Fabrication Operations.* The contractor quality activity shall support fabrication operations, including assembly, to ensure that characteristic and design criteria specified in technical documents are obtained and maintained in all contractor fabricated articles. Detailed fabrication documents shall be generated and utilized by personnel conducting fabrication operations. Fabrication documents shall include or refer to:

   a. Nomenclature and identification of the article to be fabricated.

   b. Tooling, jigs, fixtures, and other fabrication equipment to be utilized.

   c. Characteristics and tolerances to be obtained.

   d. Detailed procedures for controlling processes and cleaning, preservation, and packaging operations.

   e. Special conditions to be maintained such as environmental controls, specific cleanliness levels, and precautions to be observed.

   f. Workmanship standards.

   g. Inspection and test operations to be performed during fabrication.

   h. Special handling equipment and protective devices.

2. *Article and Material Controls.* Controls shall ensure that only conforming articles and materials are released and used and those not required for the operation involved are removed from work operation. Articles having definite characteristics of quality degradation or drift with age and/or use shall be marked to indicate the date, test time or cycle the critical life was initiated and the date, test time or cycle the useful life will be expended, and this same information shall be recorded in log books. Recorded data shall be maintained for such articles in accordance with documented requirements. Articles and materials to be fabricated or processed in a temperature controlled environment shall be inspected and tested in a similar environment to the extent necessary to prevent quality degradation. Contamination of sensitive articles and materials fabricated or processed in contamination controlled environments shall be inspected, tested, repaired, or modified in an environment equal to or cleaner than the required fabrication or process contamination control environment.

3. *Cleanliness/Contamination Control.* Contract end-items and all components, parts, etc., which form a part or are supplied with it and which are contaminant sensitive, shall be cleaned in accordance with documented procedures to the levels specified in the applicable documents and shall be maintained (refer to par 1D509-4) to that cleanliness level. In addition, the contractor shall develop a Contamination Control Document which shall consist of an index of the methods and procedures used to implement the contamination control requirements. These methods and procedures shall cover contract end-item hardware, equipment, personnel, and control of such areas as fabrication, assembly, inspection, and test. The cleanliness level of contaminant sensitive components and assemblies, beginning with acceptance at the subcontractor level and continuing until final acceptance of the item by NASA, shall be referred to in this document.

4. *Process Controls.* The contractor shall implement controls for those processes where uniform, high quality cannot be assured by inspection of articles alone. These processes include, but are not limited to metallurgical and chemical processes, metal joining processes, bonding processes, plastics application, plating and coating processes, and surface treating processes.

   a. *General.* The quality activity shall ensure the overall process control and NDE (nondestructive evaluation) effort by assuring the following:

(1) Personnel are adequately trained and certified for critical processes and NDE.

(2) Critical techniques and processes have been certified.

(3) Facilities, equipment, and materials have been installed properly and their use and maintenance are controlled.

(4) Resulting documentation, feedback, and records are controlled.

(5) Adequate coordination with the cognizant engineering function to assure proper selection of critical process NDE methods and adequate identification on drawings.

(6) Training and personnel and process certification procedures have been written and are acceptable for use.

b. *Nondestructive Evaluation.* Nondestructive evaluation methods, such as radiography, ultrasonic testing, dye penetrant inspection, magnetic particle, and other applicable methods, shall be utilized and controlled to ensure high quality hardware. The contractor shall describe in the quality program plan the integrated approach to NDE, including organizational assignments, facilities, standards, and procedures. NDE standards shall be prepared considering the flight hardware configurations and geometry and shall represent as naturally as possible the potential variations resulting from fabrication, assembly, test, and flight operations.

c. *Process Control Procedures.*

(1) Process procedures shall be prepared to implement applicable processing requirements and shall include detailed performance and control provisions. The provisions shall describe the preparation of the processing equipment and materials; the preparation of the articles or materials to be processed; detailed processing operations; conditions to be maintained during each phase of the process including environmental controls; the methods of verifying the adequacy of processing materials, solutions, equipment, environments, and their associated control parameters; and the required records for documenting the results of process inspection, test, and verification. The procedures shall fulfill the applicable test and inspection planning requirements of paragraph 1D505 for both the processing and its inspection.

(2) Precision cleaning, contamination control, and cleanliness test processes require the implementation of the above controls. Specific cleanliness levels to be maintained for systems, subsystems, and major components shall be indicated or referred to on drawings, specifications, or other documents controlling the manufacture and test of those items.

(3) The contractor shall maintain an up-to-date listing of all critical process control procedures and critical process specifications used in the fabrication, control, and inspection of the materials and articles fabricated. Critical process specifications shall be available for NASA review. The contractor shall also furnish similar information from the subcontractors upon request.

d. *Equipment Certification.* The contractor shall provide for the certification of equipment for selected processes. Records certifying that tests have been performed and the results of such tests shall be maintained. Equipment shall be recertified as indicated by the results of quality surveys, inspections or tests, or when changes are made which affect process integrity.

5. *Workmanship Standards.* Where samples or visual aids showing acceptable workmanship are necessary, they shall be selected by the contractor subject to review by NASA or its designated quality representative. Standards shall be reviewed and revised or replaced, as necessary, to satisfy current requirements. Standards shall contain appropriate product acceptance/rejection criteria.

6. *Control of Temporary Installation.* The contractor shall control and monitor articles on the vehicle which are to be installed and removed, including shipping and handling protective materials.

Temporary articles shall carry distinct identification. Temporary installations and removals shall be recorded on a single log for each vehicle. This log shall be initiated upon introduction of the first temporary installation. This log will be maintained during subsequent efforts throughout the life of the vehicle.

1D505 TESTING, INSPECTIONS, AND EVALUATIONS

1. *Testing, Inspection, and Evaluation*

   a. The contractor shall plan and conduct inspections and tests which demonstrate that contract, drawing, and specification requirements have been met on all articles and materials, procured and produced. These shall provide the assurance and documented objective evidence that the quality inherent in the design is maintained throughout the contract.

   b. The contractor shall document within the Quality Plan the integration of the inspection methods used throughout all phases of the contract. The plan shall denote an inspection flow that is in consonance with the manufacturing and test flow with significant inspection stations being identified. The plan shall demonstrate how the use of sampling plans and the quality assurance designee technique to support manufacturing and test operations is integrated into the inspection flow.

2. *Inspection and Test Planning.* The contractor shall provide the necessary planning functions for the accomplishment of inspections and tests and an adequate documentation system which substantiates their accomplishment. This planning function shall provide for:

   a. Orderly and timely inspection and testing throughout all phases of contract performance;

   b. Coordination and sequencing of inspection and testing conducted at successive levels of assembly to ensure satisfactory articles and materials and to minimize unnecessary testing;

   c. Economical and effective use of equipment, facilities, and personnel;

   d. Availability of calibrated inspection and test equipment;

   e. Coordination of inspections and tests conducted by the designated Government quality representative; and

   f. Use of hardware characteristics which have been identified based on design and end-use consideration (paragraph 1D501-1).

   The contractor shall, during the earliest practical phase of performance, conduct a complete review of the requirements of the contract to identify and make timely provision for the special controls, processes, test equipment, fixtures, and tooling requirements for assuring or assessing product quality. When production jigs, fixtures, tooling masters, templates, patterns, and such other devices are used for inspection, their accuracy prior to release for use shall be a consideration of the contractor's quality and manufacturing planning functions.

3. *Test Specifications.* The contractor shall review for concurrence, prior to release, test specifications which have been prepared for each test to be performed. Effective implementation of these documents shall be assured through controls administered by the quality activity.

4. *Inspection and Test Procedures.* Procedures shall be readily available to inspection and test personnel and shall be physically located at the applicable location at the time of inspection or test. Each procedure shall include, as applicable:

   a. Nomenclature and identification of the test article or material.

   b. Characteristics and design criteria to be inspected or tested, including values and tolerances for acceptance and rejection.

   c. Identification of characteristics and design criteria established for inspection or test by the designated Government quality representative.

d. Detailed steps and operations to be taken in sequence, including verifications to be made before proceeding.

e. Cross-reference of characteristics with measuring and/or NDE equipment to be used, specifying range and type.

f. Details or instructions for operation of special data recording equipment, or other automated test equipment.

g. Layout and interconnection of test equipment and articles.

h. Identification of hazardous situations or operations.

i. Precautions to comply with established safety requirements, ensure safety of personnel, and to prevent damage or degradation of articles and measuring equipment.

j. Environments and other conditions to be maintained.

k. Workmanship standards.

l. Constraints on inspection or testing.

m. Special instructions for nonconformances, anomalous occurrences or results.

n. Details of sampling plans to be used.

o. Details of nondestructive evaluations.

5. *Inspection and Test Performance*

a. *Inspections and Tests.* Inspections and/or tests shall be established and performed on articles and materials to verify compliance with specifications and procedures. The inspections also will include records review. The contractor shall ensure that each inspection and test operation (and to the extent practicable, each fabrication and assembly operation) is traceable to the individual responsible for its accomplishment.

(1) *Control of Articles*

(a) Articles shall be inspected and tested in accordance with applicable technical documents.

(b) Articles undergoing test shall not be adjusted, modified, repaired, reworked, or replaced except as specified in established documents, or in accordance with the requirements of paragraph 1D506.

(2) *Control of Inspection and Test Environments and Equipment*

(a) Environments shall be controlled to prevent compromising the quality of the article.

(b) Equipment shall be controlled, maintained, and calibrated as specified in procedures for each equipment.

(3) *Criteria for Reinspection and Retest.* Reinspection and retest may be required at any stage of contractor operations after accomplishment of remedial and preventive action when:

(a) The article or material does not meet the contract or contractor specification requirements; or

(b) The inspection or test performed is not in accordance with test specifications or inspection and test procedures; or

(c) Equipment malfunctions occur; or

(d) Modifications, repairs, replacements, or rework of the article or material occur after the start of inspection or testing; or

(e) The article or material is subject to drift or degradation during storage or handling; or

(f) Specified by MRB (Material Review Board). Retest shall be limited by consideration of remaining useful life and operating time for qualification.

b. *Qualification Test Articles.* The contractor shall verify that the following records and procedures are available:

(1) Manufacturing and inspection records.

(2) End-item inspection and test specifications and procedures.

(3) Authorized deviations.

(4) Nonconformances.

(5) Approved waivers.

(6) Removal and installation records.

(7) Operating time records.

(8) Change verification records.

(9) Safety procedures.

(10) Emergency shutdown procedures.

(11) Rework and retest criteria.

(12) Procedures for use of special measuring devices.

c. *End-item Inspection and Tests.* The contractor shall perform inspections and tests of completed end-items intended for delivery under the contract. Nonconformances discovered prior to start or during and after testing shall be documented and understood prior to succeeding operations. Nonconformances shall be closed out in accordance with paragraph 1D506 prior to shipping. The inspections and tests shall be performed in accordance with the end-item test specifications and procedures. In addition to determining contractual conformance, the contractor shall report immediately to NASA and the designated Government quality representative any unusual phenomenon, occurrence, difficulty, or questionable condition, whose detection and correction is not specifically contained in the applicable requirements in order that necessary actions can be initiated. The contractor shall stop testing when safety of personnel is in jeopardy or damage to the end-item or associated test equipment is possible.

d. *End-item Reinspection and Retest.* Adjustments, modifications, repairs, replacements, or rework after completion of end-item inspections and tests for the purpose of Government acceptance shall require prior approval of the designated Government quality representative. The contractor shall evaluate the conditions involved and recommend to the representative the extent of reinspection and/or retest necessary. Any additional rework, repair, or modification which is to be accomplished after the end-item is initially accepted by the contractor must have appropriate planning prepared to cover the work. The planning developed shall be processed and approved in the same manner as original planning.

e. *Pre-installation Tests.* Functional tests or inspections will be performed on components prior to installation into next higher assembly when any of the following circumstances exist:

(1) No previous acceptance test.

(2) Acceptability cannot be verified by test of next higher assembly.

(3) A significant time has elapsed since the last test. Such time period shall be determined from the age/life characteristics of the component.

(4) Where the component, once installed in the next higher assembly, is difficult to remove and requires significant schedule time to replace.

(5) Where prior failure history of the component indicates the need for pre-installation testing.

(6) Where the component, once installed in the next higher assembly, by its failure could damage the next higher assembly during test.

6. *Inspection and Test Records and Data*

a. The contractor shall generate and maintain records and data of all inspections and tests performed. The records and data generated shall be appropriate for the particular type, scope, and importance of the inspection or test operation performed and in sufficient detail and extent to provide for complete verification and evaluation of the operations and objectives. Records shall disclose the status of articles and materials and evidence of inspections and tests performed, including the dates.

b. *Equipment Records.* The contractor shall prepare, maintain, and update the equipment record for each subsystem as a means of documenting its continuing history. Each record shall be identifiable to the pertinent equipment and shall be maintained in chronological order to account for all fabrication, assembly, inspection, and test operations, as well as idle periods (storage) and movements of equipment. Entries shall be complete, self-explanatory, traceable to the individual and organization making the entry, and should include or refer to details such as the following:

(1) Configuration data: parts list, drawings, specifications, changes, and identification data.

(2) Fabrication and assembly history: buildup and disassembly instructions, repairs, rework, and modifications.

(3) Inspection and test records: specifications, procedures, results, variables data.

(4) Nonconformance summary: initial review and MRB actions, remedial and preventive actions, NASA approvals.

(5) Cumulative operating times or cycles.

(6) Maintenance records.

The contractor shall identify the equipment for which records will be prepared, the level of assembly or operation at which they will be initiated, and requirements for submittal or shipment to equipment destination. Subsystem records shall be combined into system records. When a subsystem is operated or handled independently, including removal from its system, its record shall be maintained current. The equipment records for pressure vessels shall be prepared and submitted in accordance with the applicable IRL/IRD.

c. *End-item Acceptance Data Package.* The contractor shall prepare an acceptance data package for each end-item required by the contract. The data package shall be submitted as specified in the applicable IRL/IRD.

7. *Contractor Quality Assurance Actions*

a. Prior to testing, the contractor's quality activity shall:

(1) Verify that applicable inspection and test documents are available and approved.

(2) Ensure that requirements for selection and control of articles have been implemented and that test constraints, including environmental considerations, have been resolved.

(3) Verify that all test equipment is within calibration requirements and that all personnel certifications (where certifications are required) are valid.

(4) Notify the proper Government quality representative, where required.

(5) Verify that test facility requirements have been implemented and that the facility and GSE are in the correct configuration and ready for test.

(6) Verify the configuration and that the article is ready for test and concur in start of testing.

b. During testing, the contractor's quality activity shall:

(1) Ensure that testing is accomplished in accordance with test specifications and procedures.

(2) Ensure complete and accurate recording of data and test results.

(3) Document rework, repair, or modification occurring during the test operation.

(4) Document nonconformances and their dispositions.

c. Subsequent to testing, the contractor's quality activity shall:

(1) Ensure proper disposition of articles.

(2) Report any additional nonconformances and their dispositions.

(3) Ensure that remedial and preventive action has been accomplished relative to nonconformances.

(4) Verify that test results and reports are accurate, complete, and traceable to the tested articles.

8. *Walk-through/Shakedown Inspection.* The contractor quality organization shall prepare for and conduct periodic walk-through/shakedown inspections on the contract end-item in the fabrication and assembly cycle. At NASA's option these inspections shall be to support major move points and/or as determined by hardware defect rates, routine inspection results, quality trends, and maturity of the manufacturing process. The contractor's quality organization shall identify the major move points in the fabrication and assembly cycle at which this walk-through/shakedown inspection will be performed and the major articles(s) to be inspected. The contractor's quality organization will develop walk-through/shakedown inspection planning documentation for workmanship, appearance, inspection status, and configuration status to be evaluated. The cognizant NASA resident representative will be notified in sufficient time to participate in the inspections. A copy of the accepted document shall be provided to NASA at the completion of the walk-through/shakedown inspection.

9. *Quality Assurance Designees.* The contractor may develop a systematic technique to designate certain trained and qualified manufacturing and test personnel to represent the quality assurance organization in performance of selected inspection functions to the extent that it is economically advantageous. The quality control functions of the designees shall be performed as part of their regular manufacturing and/or test function. This technique shall be described in the Quality Plan. This technique shall include the identification of hardware, fabrication processes, manufacturing flow, and inspection points. The selected inspection and test functions shall exclude those processes, inspections, and tests which are considered critical or cases where reinspection cannot be readily accomplished due to further assembly or installation of the hardware.

10. *Vehicle Access Control.* Organizational responsibilities shall be designated for all activities in and around the vehicle at all times during manufacture, assembly, test, and checkout to ensure the preservation of inherent quality and reliability achieved by design and construction. To ensure safety of the vehicle, adequate controls shall be established and implemented to limit access and maintain required environments during all operations and during periods after completion of vehicle checkout, such as storage.

11. *GSE Access Control.* Any Space Shuttle GSE which directly monitors and or controls the Shuttle vehicle during checkout and launch and which, due to its design, normally requires opening to perform modification, inspection, or repair should be included in an access control system after validation and inspection acceptance.

12. *Integrity Control.* Controls shall be established, documented and maintained by the contractor and applicable suppliers to ensure that the integrity of hardware is not jeopardized through such operations as unpacking, receiving, inspection, storage, testing, installation, integration testing and shipping.

1D506 NONCONFORMING ARTICLES AND MATERIALS

1. *Nonconforming Article and Material Control.* When an article or material, produced or procured by the contractor or its subcontractor prior to the time of Government acceptance, does not conform to applicable drawing specifications or other requirements, it shall be identified as nonconforming, segregated to the extent practicable and held for review action. Articles and materials which have received Government acceptance (see Glossary for definition of "acceptance") shall be subject to the requirements of Section 1D511, Government Property Control. The contractor shall establish a documented systematic technique for the identification, documentation, and control of nonconforming hardware. This technique shall provide that all hardware be identified in a manner such that marking will in no way degrade the article's required performance nor be incompatible with the design environment of the article. If too small to mark, the article shall be tagged. This identification shall be made immediately after the nonconformance is noted and/or the hardware is removed, if installed. The contractor shall provide a means for contractor's quality activity acceptance overstamping the previous nonconformance marking. This will indicate that the nonconforming hardware has been analyzed, and acceptability achieved. Hardware procured by the contractor for direct shipment from the vendor or subcontractor to NASA shall not be shipped, with open nonconformance, without prior NASA approval.

2. *Nonconformance Reporting and Correction.* The contractor shall:

   a. Establish a controlled, closed loop documentation technique for recording, reporting, analyzing, correcting, verifying, and feedback data on nonconformances (discrepancies) discovered by the contractor, subcontractor and supplier personnel, and the designated Government facility representative(s).

   b. Maintain records of discrepancies and their dispositions. In addition, all records of MRB (Material Review Board) actions will be maintained and available to NASA for review. The documents prepared and issued for each discrepancy will contain as a minimum:

      (1) A unique and traceable number;

      (2) The nomenclature and identification of the nonconforming article or material;

      (3) A description of the required characteristic or design criteria and the nonconformance;

      (4) Cause or reason for the nonconformance;

      (5) Preventive and/or corrective actions taken or recommended;

      (6) Disposition (remedial action) of the nonconforming article or material;

      (7) Initiator of the document;

      (8) Signatures of authorized personnel;

      (9) Date that the nonconformance occurred;

      (10) Type of activity being conducted: e.g., fabrication, assembly, qualification test, systems test, predelivery or preinstallation acceptance test, etc.; reference must be made to applicable procedure numbers;

      (11) Area function or activity responsible for causing the failure or discrepancy;

      (12) Classification of the nonconformances (NASA action required/not required); and

      (13) Reference to documented repair procedures, as applicable.

   c. Accumulate nonconformances in summary and trend reports.

   d. Commence nonconformances recording upon initiation of manufacturing for development and flight hardware, launch complex, and related support equipment, and continue through all subsequent phases of the contract.

(1) Record each nonconformance observed or encountered during inspection of flight equipment and GSE in order to initiate corrective action (via MRB, if appropriate). These recordings will also allow the establishment of quality trends.

(2) Record each failure encountered in testing, checkout, or operation of flight equipment and GSE including those caused by human error.

e. Conduct appropriate analysis and examination of nonconforming articles, materials, or conditions to determine the cause or reason for the nonconformance. Nonconforming articles or materials may be forwarded to the NASA as requested by the NASA contracting officer.

f. As a minimum:

(1) Notify responsible contractor or supplier organizational elements of nonconformances and the need for remedial and preventive action.

(2) Assign responsibility for followup of remedial and preventive actions to ensure accomplishment.

(3) Conduct timely and effective remedial action to ensure the correction of the article or material.

(4) Conduct timely and effective preventive action to prevent recurrence of the nonconformance including correction of technical documents, correction of other identical articles or materials at all locations and the prevention of detrimental side effects.

(5) Appropriately document analyses and remedial and preventive actions.

(6) Closeout nonconformance documentation after verifying that effective remedial and preventive actions have been taken.

(7) Notify the NASA of nonconformances and their related remedial and preventive actions, as established by contract.

g. Initially review nonconforming articles and materials to determine one of the following listed dispositions. When the disposition affects contract requirements, the NASA contracting officer approval shall be required. Articles and materials shall be withheld from further processing until appropriate approval is obtained.

(1) *Waivers/Deviations.* Waivers/deviations may be submitted to the contracting officer for approval prior to or as a result of consideration of other dispositions. Each waiver/deviation shall be submitted with written recommendations and proposed remedial and preventive action.

(2) *Return to Supplier.* When an article or material is found to be nonconforming on receipt, it should be returned to the supplier. The contractor shall provide the supplier with nonconformance information and assistance, as necessary, to permit remedial and preventive action.

(3) *Return for Rework or Completion of Operations.* If the nonconformance is in the category of "return for completion of operations" or "return for rework to drawings, specifications or procedures," the article or material shall be returned for rework or completion using established technical documents and operations. During such rework, the articles or material shall be resubmitted to normal inspection and/or test operations.

(4) *Repair per Standard Repair Procedure.* If a repair is possible and a standard repair procedure is in existence and has been approved by the MRB for use in the specific application, the repairs may be accomplished in accordance with the approved procedure without MRB action. If the procedure is changed, then it will again require full MRB approval.

(5) *Scrap.* If the article or material is unfit for use, it shall be dispositioned in accordance with Government approved contractor procedures for identifying, controlling, and disposing of scrap. Considerations should be given to alternate use of the scrapped article for contractor or NASA training programs, engineering laboratory work, etc., in order to minimize the financial loss resulting from scrap dispositions. The contractor shall assure that scrap is accounted for as to its end use, and that it is not to be used for flight hardware. In addition, the contractor shall identify remedial actions taken to reduce costs resulting from scrappage of nonconforming articles and materials.

(6) *Submit to Material Review Board.* When the dispositions as described above are not appropriate, the article or material shall be submitted to the MRB for final disposition.

h. Articles and materials disposed of without referral to the MRB shall be subject to a review of each case by the designated Government quality representative to verify appropriateness of contractor decisions.

3. *Material Review Board*

a. *Membership.* The MRB shall be comprised of at least one contractor representative whose primary responsibility is engineering and one contractor representative whose primary responsibility is product quality, and a NASA quality representative. However, the MRB may function without the NASA quality representative upon agreement by NASA when dispositioning nonconformances on articles or materials whose failure would not affect the safety of the crew or success of the mission. Contractor members for the MRB shall be selected by the contractor on the basis of technical competence and shall have sufficient authority to make appropriate dispositions of the articles or materials involved. Copies of the MRB actions will be submitted to the NASA representative.

b. *Responsibility.* As nonconformances are presented for MRB review, the contractor's quality representative, in conjunction with the other MRB members, shall:

(1) Evaluate material submitted.

(2) Determine or recommend disposition, such as scrap, repair, etc., or exercise the option of recommending dispositions to the NASA contracting officer.

(3) Approve the method and procedure for repair, when repair is appropriate.

(4) Provide contractor recommendations to the contracting officer concerning nonconformance dispositions requiring his/her approval and verify implementation after approval is obtained.

(5) Ensure that effective remedial and preventive actions are documented on the nonconformance document.

(6) Ensure that accurate records of MRB actions are maintained.

c. *MRB Dispositions.* Dispositions, other than scrap, require the unanimous agreement of the applicable board members. In determining dispositions, the board shall: consider the effect of the nonconformance upon the intended use; classify nonconformance for processing on a priority basis; review records of earlier review actions affecting the same or like article or material; and consider the recommendations of personnel acting in an advisory capacity. The board shall specify on the nonconformance document one of the following dispositions. When the disposition affects contract requirements, the NASA contracting officer approval shall be required. Articles and materials shall be withheld from further processing until appropriate approval is obtained.

(1) *Waivers/Deviations.* Refer to paragraph 1D506-2g(1).

(2) *Repair.* When, in the opinion of the Board, an acceptable repair is possible, repair action may be authorized. Procedures shall be established or approved by the MRB to perform this

repair. Procedures shall include appropriate inspections and tests to verify the acceptability of the repair. Standard repair procedures, if developed, shall be under the control of the MRB. Standard repair procedures shall be approved by the MRB, including the NASA quality representative. The MRB may grant authority to apply these approved standard repair procedures for similar nonconformances. The standard repair procedure shall identify hardware applicability, extent of characteristic nonconformance, detailed instruction for accomplishing the repair, and inspection/test criteria for the repaired article or material. The existence of standard repair procedures shall not relieve the contractor of the responsibility for initiating preventive action to the fullest extent practicable.

(3) *Use-as-is.* Nonconformances which the MRB feels are suitable for use without repair may be authorized for use-as-is. The rationale for making a use-as-is disposition shall be documented on the nonconformance report.

(4) *Scrap.* Refer to paragraph 1D506-2g(5).

d. *MRB Holding Area.* The contractor shall establish holding areas for articles and materials submitted to the MRB. These holding areas shall provide for the following:

(1) Access limited to MRB members, personnel escorted by an MRB member, and quality personnel administering the area. The contractor shall make provisions to prevent unauthorized entrance when area is not attended and to preclude removal of hardware except in accordance with the approved MRB disposition.

(2) Storage facility.

(3) Log book for recording location and status of articles and materials.

(4) Posting of the current list of the names of authorized personnel, including MRB members.

e. *Supplier Material Review Board.* The contractor may, upon determining that a supplier possesses the capability to meet MRB requirements to the extent approved by NASA or its designated Government quality representative, delegate MRB responsibility to the supplier. The contractor will limit the authority of the subcontractor's MRB dispositions to nonconformances not requiring waiver action. Nonconformances requiring waiver action shall be processed in accordance with the applicable contract provisions.

f. *Repair Controls.* The contractor shall prepare manufacturing documents to accomplish repair operations, including standard repairs. Prior to initiation of work, the contractor shall review these documents to assure that they provide detailed step-by-step instructions, material requirements, dimensional and process parameters, and any other considerations imposed by the MRB disposition. Appropriate inspection and test accomplishment shall be verified by the contractor to verify the acceptability of the repair. Repair records and data traceable to the affected article shall be maintained on file by the contractor.

4. *Contracting Officer.* Nonconformances and dispositions shall be subject to the contracting officer's approval as stated above. Waivers/deviations may be submitted prior to or as a result of MRB action. Each waiver/deviation shall be submitted with written recommendations and proposed remedial and preventive action. Articles and materials shall be withheld from further processing until appropriate approval is obtained.

1D507 METROLOGY

1. *Metrology Controls.* The contractor shall establish and utilize a documented metrology activity to control measurement processes in order to provide objective evidence of quality conformance. Measurement processes shall be performed in accordance with established written procedures.

2. *Acceptance.* Prior to use during articles and materials acceptance, the contractor shall ensure that all measurement standards and equipment are inspected and/or tested to ensure conformance with

requirements. Documented results of the inspection and/or tests shall be maintained by the contractor.

3. *Evaluation.* All special measurement standards and equipment (e.g., automatic test and checkout equipment) shall be evaluated under intended operating conditions to verify that:

   a. When used in the intended measurement process, the standards and equipment measure the desired characteristics to the required accuracy and provide the desired indications or records.

   b. Standards and equipment are compatible with the configuration of related hardware and environment conditions.

   c. Operating instructions are correct and complete. Documented results of the evaluations shall be maintained by the contractor.

4. *Article or Material Measurement Processes.* Random and systematic errors in any article or material measurement process shall not exceed ten percent of the tolerance of the article or material characteristic being measured. Authorization for exception shall be requested from the procuring NASA installation.

5. *Calibration Measurement Processes.* Random and systematic errors in any calibration measurement process shall not exceed 25 percent of the tolerance of the parameter being measured. Authorization for exception shall be requested from the procuring NASA installation.

6. *Calibration Controls*

   a. *Facility.* The contractor shall have its own or use the services of an outside facility for the calibration of measurement standards and equipment.

   b. *Traceability.* All measurement standards shall be traceable to standards maintained by the National Bureau of Standards or their value(s) shall be derived from a controlled measurement process utilizing a fundamental constant of nature.

   c. *Handling, Storage, and Transportation.* All measurement standards and equipment shall be handled, stored, and transported in a manner which shall not adversely affect quality or result in hazardous conditions.

   d. *Identification and Labeling.* All measurement standards and equipment shall be uniquely identified and labeled, tagged, or coded to indicate calibration status and due date of next calibration.

   e. *Calibration Intervals.* Calibration intervals shall be established and periodically reviewed to maximize the availability of measurement standards and equipment without adversely affecting quality. Intervals shall depend upon the use, accuracy, type of standard or equipment, required precision, and other conditions adversely affecting the measurement process.

   f. *Recall System.* All standards and equipment used in measurement processes shall be recalled and recalibrated at established intervals. Standards and equipment not recalibrated before the recall due date shall be removed from service or otherwise restricted from use. Authorization for exception shall be obtained from NASA. Controls shall be established to ensure the immediate recalibration or removal from service of those found to exceed the established interval or which for any reason might have an adverse affect on quality.

   g. *Calibration Records.* The contractor shall maintain individual records of measurement standards and equipment. These records shall include, but not be limited to, the following:

      (1) Identification of standard or equipment to be calibrated.

      (2) Identification of standard, equipment, and calibration procedure utilized in the calibration process.

      (3) Calibration intervals.

(4) Dates and results of each calibration.

(5) Due date of next calibration.

(6) Individual(s) performing calibration.

(7) Calibration facility.

(8) Degree of nonconformance of standards or equipment received for calibration.

7. *Environmental Requirements.* Environmental characteristics (e.g., temperature, humidity, vibration, cleanliness) shall be compatible with the accuracy requirements of the article and material and calibration measurement processes.

8. *Remedial and Preventive Action.* Remedial and preventive action shall be taken relative to nonconforming measurement standards or equipment and shall extend to the article or material measured when such equipment has been used in end item final acceptance tests.

1D508 STAMP CONTROLS

1. *Stamp Control.* The contractor shall establish and maintain a documented stamp control technique, including written procedures, that provides for the following:

   a. Stamps, decals, seals, torque wax, paints, signatures, etc., shall identify that articles and materials have undergone source and receiving inspection, in-process fabrication and inspection, end-item fabrication and inspection, end-item testing, storage and shipment. .

   b. Stamps shall be traceable to individuals responsible for their use and records shall be maintained to identify individuals with specific stamps. Unissued stamps shall be kept secure to prevent unauthorized use. Stamps issued to personnel being transferred or terminated shall be returned and shall not be reissued for a period of at least six months. Worn or damaged stamps shall be destroyed at the time replacements are issued. The identification symbol (number, letter, etc.) of lost stamps shall be withdrawn from use for a period of one year before reissue. The use of any stamp by an individual other than the holder of record is specifically prohibited. Periodic stamp audits shall be conducted to verify that stamps are in the possession of the individuals to whom they are issued.

   c. Stamps shall be applied to records to indicate the fabrication or inspection status of associated articles and materials.

   d. Stamps shall be applied to tags, cards, or labels attached to individual articles and materials or their containers, as appropriate.

   e. Stamps indicating that fabrication, inspection, or test operations have been performed may be applied directly to articles and materials except when this is impractical due to physical limitations of the article or such applications will compromise their qu- .y.

   f. Stamping methods and marking materials must be compatible with the articles and their use.

   g. The contractor shall maintain an up-to-date description and explanation of the significance of all stamps and shall have, as a minimum, a unique identification or mark for acceptance, for holding a nonconformance pending MRB disposition, rejection, MRB approval, and special process or nondestructive evaluation and/or inspection acceptances.

2. *Stamp Restriction.* The designs of contractors' stamps shall be such that fabrication and inspection stamps are distinctly different and contractor stamps shall not exhibit the designation "NASA" or abbreviations of any NASA installation.

1D509 HANDLING, STORAGE, PRESERVATION, MARKING, LABELING, PACKAGING, PACKING, AND SHIPPING

1. *Procedures and Instructions Control.* The contractor's quality activity shall review for concurrence, prior to release, those procedures and instructions which describe in detail the controls for handling,

storage, preservation, marking, labeling, packaging, packing, and shipping operations. Effective implementation of these documents shall be assured through controls administered by the quality activity.

2. *Handling.* The contractor's quality activity shall verify that manufacturing planning documents (routing sheets, operations sheets, travellers, etc.) contain handling instructions and the identification of any special handling equipment used to prevent handling damage. Hardware that may be susceptible to damage shall be provided with special covers, containers, boxes, carts, or vehicles to prevent damage during fabrication and processing. All installation, test, and operational sites shall be provided copies of handling instructions to enhance preventive handling damage. Evidence of initial and periodic proof-testing of applicable handling equipment shall be maintained.

3. *Storage.* The contractor shall control storage areas for stored articles and materials that are not in work. The controls shall include:

   a. Controlled acceptance into and withdrawal from the storage area.

   b. Positive identification of limited-life material and removal of materials whose shelf life has expired.

   c. Periodic inspection of stored material, housekeeping, and record keeping.

   d. Systematic inspection and/or testing necessary to insure maintenance of preservation, including special environments, for articles in long-term storage.

4. *Preservation.* The contractor shall ensure that articles and materials subject to deterioration, corrosion, or contamination through exposure to air, moisture, or other environmental elements during storage and fabrication are cleaned and preserved by methods which ensure maximum protection consistent with life and usage. The contractor shall verify that preservation instructions, including material and process definition, are contained in the contractor's manufacturing documents and are accomplished.

5. *Packaging.* The contractor shall verify that packaging material, procedures, and instructions are utilized and provide for protection of articles and materials while at the contractor's plant, during transportation to destination, and after arrival at destination. The contractor may utilize existing specifications (industrial or Government) or develop and document special specifications to ensure maximum protection. Special attention shall be directed toward critical, sensitive, dangerous or high-value articles. The contractor shall ensure that packaging operations are specified in the manufacturing documents, that sufficient detail is included to ensure the integrity of the packaging and the hardware, that specific internal environments necessary to prevent degradation of the article or material are included in the packaging. The contractor shall verify the accomplishment of packaging operations.

6. *Packing.* The contractor shall perform inspection operations, as necessary, to ensure that articles or materials are ready for packing, are not damaged during packing operations, and that packing meets the specified requirements. When reusable containers are to be used, they shall be inspected prior to each use to ensure completeness and suitability.

7. *Marking and Labeling.* The contractor shall ensure that appropriate marking and labeling for packaging, storage, and shipping of articles and materials is performed in accordance with applicable specifications. The marking shall include such information as complete article or material identification, cleanliness level, environmental requirements, package orientation arrows, caution and warning notes, life expiration dates, location of data package, and transportation information, as applicable. Special attention shall be given to critical, clean, sensitive, dangerous, and high-value articles. Tamper-proof decals or labels shall be utilized on precision cleaned articles to permit ready detection of loss of packaging integrity.

8. *Shipping*

a. *Control.* The contractor shall implement controls for articles and materials to be shipped from the contractor's plant and shall verify that:

(1) All fabrication, assembly, inspection, and testing operations authorized and required to be performed at the plant or test site have been satisfactorily completed.

(2) Articles and materials have been prepared and packaged in accordance with applicable procedures and requirements and have been properly identified and marked. In the absence of special packing and marking requirements in the contract, packing and marking shall comply with Interstate Commerce Commission rules and regulations and shall ensure safe arrival and ready identification at destination.

(3) Accompanying documents have been properly identified as to inspection status by appropriate contractor stamps, and that the data package is complete.

(4) Handling devices and transportation equipment are suitable for the articles and materials involved to prevent damage.

(5) The loading and transportation methods conform to applicable specifications and requirements.

b. *Unscheduled Removal.* The contractor shall notify the NASA or the designated Government quality representative in the event of any unscheduled removal of an article or material from its container. The extent of reinspection and retest shall be as authorized by the NASA or the designated Government quality representative.

c. *Acceptance Data Package.* The contractor shall include a complete documentation package with every shipment. The location of the data package shall be indicated on the exterior of the shipping container.

1D510 SAMPLING PLANS, STATISTICAL PLANNING AND ANALYSIS

1. *Sampling Plans.* Sampling plans may be used when inspection or tests are destructive or data, inherent characteristics, or the noncritical application of an article or material indicates that a reduction in inspection or testing can be achieved without jeopardizing achievement of quality, reliability, or design intent. When sampling techniques are to be employed, existing military sample inspection documents shall be utilized to the degree practicable. Sampling plans, other than those contained in existing military documents, may be utilized by the contractor after approval of NASA or its designated Government quality representative. The plan(s) shall be as specified in applicable IRL/IRD.

2. *Statistical Analysis.* Statistical analysis techniques may be used where such use will provide effective control over fabrication and inspection operations, especially in those areas where special processes and equipment are difficult to control. Statistical charts may be maintained at a location that will provide maximum preventive action utilization.

1D511 GOVERNMENT PROPERTY CONTROL

1. *Contractor's Responsibility*

a. The contractor shall be responsible and accountable for all Government property and associated documentation supplied by the Government. The contractor shall maintain and update all equipment logs supplied with the equipment.

b. Controls shall be established, documented, and maintained by the contractor and applicable suppliers to ensure that the integrity of Government property is not jeopardized or compromised through all operations including unpacking, receiving inspection, storage, testing, installation, integration testing, and shipping, as applicable. The contractor's Quality Plan will, as a minimum, refer to the procedures for controlling Government property.

c. Upon receipt, the contractor shall inspect Government property to the extent practical to detect damage in transit and to verify that the article and its acceptance data package are complete and the article is as specified in the shipping documents. Under no circumstances shall an article be unpacked and subjected to receiving inspection environment until a review has been made of the environmental requirements of the particular article to ensure that the integrity of previously accomplished inspection and cleaning procedures is maintained. Articles found to be serviceable, after packaging has been opened, shall be represerved and repackaged unless the articles are to be used immediately.

d. Should there be evidence of damage in transit, the article shall be inspected to determine the extent of damage.

e. Receipt of Government property and accomplishment of receiving inspection functions, whether successful or not, shall be recorded in the historical record for the article. This shall include identification of property, dates, types and results of contractor inspections, tests, and other significant events.

f. Receiving inspection and/or testing functions shall be performed by or witnessed by contractor quality personnel. NASA or its designated representative may participate in the inspection of Government property upon receipt at the contractor's or supplier's plant. The contractor shall functionally test Government property upon receipt or prior to installation into the next level of assembly when required by paragraph 1D505-5e.

g. The contractor shall provide an approved storage area for Government property. Control of this area shall provide for:

(1) Limited personnel access.

(2) Controlled receipt and withdrawal of Government property.

(3) Identification of article status as "Acceptable," "Rejected," "Awaiting Test," or "Awaiting Test Results."

(4) Inventory list of articles in the area.

(5) Scheduled inspection of the area and periodic audits of the inventory list.

The contractor shall provide for the protection, maintenance, calibration, periodic inspection, segregation, and controls necessary to ensure that quality is maintained, that storage areas are adequate, and that damage and deterioration do not occur during handling, storage, installation, or shipment.

h. Written procedures shall describe the contractor's control over the storage and withdrawal of Government property.

i. Government property shall not be diverted or loaned from its assigned purpose without the prior approval of the NASA Contracting Officer or a designated representative.

j. All testing, assembly, installation, modification, and inspection operations shall be controlled in accordance with documented cleanliness requirements for environment, work surfaces, tools, fixtures, handling, storage and shipping containers and test and inspection equipment to prevent contamination or other degradation of Government property. Tests and inspections shall be performed to verify article cleanliness prior to use and at established intervals during use to ensure continued cleanliness.

2. *Unsuitable Government Property*

a. Government property found to be damaged or otherwise unsuitable for its intended use shall be identified as nonconforming, segregated to the extent practicable and held for review action. Discrepant Government property shall not be dispositioned, reworked, repaired, modified, or replaced without the specific written authorization of NASA.

b. The contractor shall ensure that all nonconformances are documented and analyzed to ascertain the probable cause. When the cause is determined to be in the contractor's operations or activities, corrective action shall be instituted to prevent recurrence.

c. Government supplied property found unsuitable for use during and subsequent to receiving inspection will be reported by the contractor to NASA or its designated representatives. The contractor will determine and report the probable cause and necessity for withholding such property from use.

d. Suppliers having control of Government property for which the contractor is responsible shall report property to the contractor and to the delegated Government representative.

1D512 FLIGHT TEST/GROUND OPERATIONS

1. *Procedures.* The contractor shall develop quality procedures to support the flight test development program and associated ground operations.

2. *Planning and Procedural Controls.* The contractor shall develop quality planning and procedural controls in conjunction with and support of horizontal and vertical flight tests and associated ground operations. This activity shall assure as a minimum, the following:

   a. Compatibility with planning and procedural controls.

   b. All quality activities relating to flight test/ground operations such as checkout, servicing, maintenance, and refurbishment are adequately defined.

3. *Turnaround Inspection and Test Surveillance.* The contractor shall support the turnaround maintenance and ground operations activity to assure that design capabilities of the hardware are maintained and that the quality of the hardware is not degraded. These activities shall include:

   a. Development of specific inspection procedures and nondestructive evaluation techniques to be used during safing, turnaround, vehicle ferrying, etc.

   b. Assurance that maintenance procedures are prepared which include a listing of the inspection and test procedures, test specifications, and processes for NDE techniques and that such documentation is available for site operations.

   c. Support of flight test activities.

   d. Definition of special equipment (NDE) required to perform major inspections.

   e. Development of data collection techniques which are compatible with the launch site operations.

   f. Development of nonconformance reporting and corrective action system.

APPENDIX A: GLOSSARY OF TERMS

Acceptance—The act of an authorized agent of the procuring organization by which the procuring organization assents to ownership of existing and identified contract items, or approves specific services rendered as partial or complete performance of a contract.

Acceptance Testing—Tests to determine that a part, component, subsystem, or system is capable of meeting performance requirements prescribed in the purchase specification or other documents specifying what constitutes adequate performance capability for the item in question.

Accident—An unplanned event which results in an unsafe situation or operational mode.

Accident Prevention—Methods and procedures used to eliminate the causes which lead, or could lead, to an accident.

Certification Testing—Certification tests consist of the subsystem qualification tests and the subsystem higher-level-of-assembly tests plus vehicle level tests. Certification testing does not include exploratory, design verification, development, prequalification, piece-part qualification, acceptance or checkout tests, except where such tests are required for certification.

Component—A combination of parts, devices, and structures, usually self-contained, which performs a distinctive function in the operation of the overall equipment. A "black box" (e.g., transmitter, encoder, cryogenic pump, star tracker.)

Corrective Action—Action taken to preclude occurrence of an identified hazard or to prevent recurrence of a problem.

Credible Accident—An accident, the scope and magnitude of which have been defined to allow the design to provide for contingency survival and/or continued operation.

Critical Process—A material process (i.e., a process which changes the chemical/physical properties of a material) which could have a significant performance effect on hardware identified on the CIL (Critical Items List), hardware designated for fracture control and ordnance, and hardware where design conformance cannot be assured by inspection.

Critical Inspection and Test Method—An inspection or test method which is used to verify a critical process.

Criticality Categories

Category	*Definition*
1	Loss of life or vehicle
2	Loss of mission
3	All others
1R	Redundant hardware element failure of which could cause loss of life or vehicle.
2R	Redundant hardware element the failure of which could cause loss of mission.

Note: For GSE, Category 2 is loss of vehicle system.

Defect—A condition of any hardware in which one or more characteristics do not conform to the specified requirements.

Design Specification—Generic designation for a specification which describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the

design specification is a statement of functional requirements with only general coverage of physical and test requirements. The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements.

Designee—Certain trained and qualified manufacturing and test personnel who represent the contractor quality assurance activity in the performance of selected quality assurance functions.

Deviation—A deviation is a specific authorization, granted before the fact to depart from a particular requirement of specifications or related documents.

Escape—The utilization of equipment or subsystems without outside assistance to effect egress from the immediate proximity of danger.

Fail-Operational—The ability to sustain a failure and retain full operational capability for safe mission continuation.

Fail-Safe—The ability to sustain a failure and retain the capability to successfully terminate the mission. For GSE, the ability to sustain a failure without causing loss of vehicle systems or loss of personnel capability.

Failure—The inability of a system, subsystem, component, or part to perform its required function within specified limits, under specified conditions for a specified duration.

Hazard—The presence of a potential risk situation caused by an unsafe act or condition.

Hazard Analysis—The determination of potential sources of danger and recommended resolutions in a timely manner for those conditions found in either the hardware/software systems, the person-machine relationship, or both, which cause loss of personnel capability, loss of system, or loss of life or injury to the public.

Hazard Levels—A hazard whereby environment, personnel error, design characteristics, procedural deficiencies, or subsystem malfunction may result in loss of personnel capability or loss of system shall be categorized as follows:

a. *Catastrophic*—No time or means are available for corrective action.

b. *Critical*—May be counteracted by emergency action performed in a timely manner.

c. *Controlled*—Has been counteracted by appropriate design, safety devices, alarm/caution and warning devices, or special automatic/manual procedures.

Integrity Control—A formalized system established to ensure that only authorized changes, modifications and entries are made to hardware.

Limited Life Item—Any item designated as having a limited useful life regardless of whether it is a limited operating life, limited shelf life, operating life sensitive, or combinations of these. This includes, where appropriate, fluids, elastromers, and polymers.

Limited Operating Life Item—Any item which deteriorates with increased accumulation of operating time/cycles and thus requires periodic replacement or refurbishment to assure that its operating characteristics have not degraded beyond acceptable limits including consideration for total mission time/cycles and safety factor margins.

Limited Shelf Life Item—Any item which deteriorates with the passage of time and thus requires periodic replacement, refurnishment, retesting, or operation to assure that its operating characteristics have not degraded beyond acceptable limits. This includes installed as well as stored components.

Loss of Personnel Capability—Loss of personnel function resulting in inability to perform normal or emergency operations. Also includes loss or injury to the public.

Loss of Vehicle System—Loss of the capability to provide the level of system performance required for normal or emergency operations.

Lot—Articles produced in a given time sequence with no changes in materials, tooling, processes, personnel, techniques or configuration.

Nonconformance—A condition of any article or material or service in which one or more characteristics do not conform to requirements. Includes failures, discrepancies, defects, and malfunctions.

Off-the-Shelf Hardware—Production or existing design hardware (black box, component) used in or for NASA, military, and/or commercial programs.

Operating Cycles—The cumulative number of times an item completes a sequence of activation and return to its initial state; e.g., a switched-on/switched-off sequence, a valve-opened/valve-closed sequence, tank-pressurized/depressurized, or dewar cryogenic exposure/drain.

Operating Life—The maximum operating time/cycles which an item can accrue before replacement or refurbishment without risk of degradation of performance beyond acceptable limits.

Operating Parameter Sensitive Item—Any item which has a limited life due to variances in its operating parameters (i.e., drift rate in gyro mechanisms) which may not be directly related to operating or calendar time.

Ordnance Device Flight Certification—An assessment of each device (by lot) which includes satisfactory premanufacture facility reviews, quality data, and destructive and nondestructive test results.

Ordnance Lot (Assembly)—Those assemblies produced in a given time sequence from a single hardware lot and a single explosive lot with no changes in materials, tooling, processes, personnel, techniques, or configuration.

Overstress—A value of any stress parameter in excess of the upper limit of the normal working range or in excess of rated value.

Part—One or more pieces joined together which are not normally subject to disassembly without destruction.

Deviated Parts—Parts deviating to some degree from their controlling specification(s).

EEE Parts—EEE (electrical, electronic, and electromechanical) parts such as transistors, diodes, microcircuits, resistors, capacitors, relays, connectors, switches, transformers, and inductors.

Substitute Parts—Parts differing from those specified in the approved equipment design.

Problem—Any nonconformance which fits or which is suspected of fitting one of the following categories:

—Failure or unsatisfactory condition occurring during or subsequent to production acceptance testing.

—Failure or unsatisfactory condition which occurs prior to acceptance testing that will or has the potential to adversely affect safety, contribute to schedule impact or launch delay, or result in design change.

—*Problem Analysis.* Documented results of the investigation performed to determine the cause of the problem.

—*Cause (Problem Cause).* The event or series of events directly responsible for the problem.

—*Closed Problem.* A problem is closed when the hardware supplier is formally notified of NASA concurrence with the problem analysis (including determination of the cause) and has implemented corrective action to preclude recurrence of the problem after acceptance tests. A lack of corrective action may be acceptable to NASA if analytical/test evidence from the hardware supplier shows that the problem is always detectable during the performance of an established test prior to use and that the problem would not occur subsequent to this test.

—*Explained Problem.* A problem is explained when the supplier is formally notified of NASA's concurrence with the problem analysis and rationale for not establishing corrective action. The rationale must establish that a planned mission may proceed with no detrimental effects should the problem recur and that a responsible NASA authority has decided that no corrective action need be established as defined for a closed problem.

—*Open Problem.* A problem for which responsible NASA management personnel have not approved the problem resolution submitted by the supplier. The problem is deemed to be open until the supplier is formally notified by NASA that resolutions are acceptable for all deliverable end items for which the problem is applicable.

—*Resolved Problem.* A problem that has been closed or explained.

Problem Reporting and Corrective Action—A controlled technique for identification, reporting, analysis, remedy, and prevention of recurrence of problems which occur throughout specified portions of the contract effort.

Program Hardware—Government and contractor furnished flight, support, and test hardware, equipment, and facilities for the Space Shuttle Program.

Reliability Numerical Estimate—A characteristic of a system or any element thereof expressed as a probability that it will perform its required functions under defined conditions at designated times for specified operating periods.

Remedial Action—Action to correct a nonconforming article or material.

Rescue—The utilization of outside assistance by means of personnel, equipment, or separately based vehicles to effect a return to a reasonably permanent safe haven.

Residual Hazard—Hazard for which safety or warning devices and/or special procedures have not been developed or provided for counteracting the hazard.

Risk—The chance (qualitative) of loss of personnel capability, loss of system, or damage to or loss of equipment or property.

Safety—Freedom from chance of injury or loss of personnel, equipment or property.

Safety Critical—Facility, support, test, and flight systems containing:

a. Pressurized vessels, lines, and components.

b. Propellants, including cryogenics.

c. Hydraulics and pneumatics.

d. High voltages.

e. Radiation sources.

f. Ordnance and explosive devices or devices used for ordnance and explosive checkout.

g. Flammable, toxic, cryogenic, or reactive elements or compounds.

h. High temperatures.

i. Electrical equipment that operates in the area where flammable fluids or solids are located.

j. Equipment used for handling program hardware.

k. Equipment used for personnel walking and work platforms.

SFP (Single Failure Point)—A single element of hardware, the failure of which would lead directly to loss of life, vehicle or mission. Where safety considerations dictate that abort be initiated when a redundant element fails, that element is also considered a single failure point.

SFPS (Single Failure Point Summary)—Summary listing of those single failure points identified in the FMEA. The SFPS amplifies the recommended corrective action for elimination or minimization of the effect associated with each failure mode or the justification for retaining the failure mode.

Survival—The utilization of equipment to provide a temporary safe haven to which personnel/crew may escape, and from which rescue may be accomplished.

System Safety—The optimum degree of risk management within the constraints of operational effectiveness, time and cost attained through the application of management and engineering principles throughout all phases of a program.

Unsatisfactory Condition—Any defect for which engineering resolution is required and which requires recurrence control beyond the specific article under consideration. Included in this definition are conditions which cannot be corrected to the specified configuration using the standard planned operations or an event which

could lead to a failed condition but does not affect the function of the article such as contamination, corrosion, workmanship requiring, engineering disposition, etc.

Waiver—Granted use or acceptance of an article which does not meet specified requirements; a waiver is given or authorized after the fact.